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RADC-TR-81-183, Vol III (of four)
Final Technical Report
July 1981

SOFTWARE MODELING STUDIES EXPERIMENTAL STUDY OF A TWO DIMENSIONAL LANGUAGE Vs FORTRAN FOR FIRST COURSE PROGRAMMERS

Polytechnic Institute of New York

Melvin Klerer

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The purpose of this study was to obtain quantitative measures of the relative performance of two very different programming languages. One language was Fortran and the other was the Klerer-May Two Dimensional Language. The report describes the experiments conducted, presents the experimental results and provides a discussion of the results obtained.

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INTRODUCTION

The purpose of this work was to obtain some quantitative measure of relative performance for two very different programming languages. One language was FORTRAN and the other was the Klerer-May (4) (K-M) two-dimensional (2-D) language. In this 2-D language, programming of most algebraic expressions requires little or no alteration of the text book form when typed on a input/output typewriter with mathematical typing capability. The general syntax of the language was designed so as to minimize the learning period of the novice user, to minimize programming error by using ordinary mathematical notation and semantics, and to be self-documenting and easily readable by anyone with a minimum of mathematical literacy.

Some of the basic style associated with the K-M 2-D programming system is illustrated by the examples to be found in appendices D and E. Programs are input by typing on a modified I/O typewriter. Half-space subscripting and superscripting are under keyboard control and arbitrary-sized common mathematical symbols may be "drawn" by the use of eight special characters that "interlock" so that the complete symbol appears to be continuous. Corrections can be made by overtyping or by pressing a special "erase" key when positioned over the unwanted character. Mathematical symbols need not be typed neatly as the system was designed to recognize highly asymmetric representations of basic symbols and to tolerate non-uniform spacing in both horizontal and vertical directions. Arbitrary back and forward spacing, up and down spacing, intermixed with typing, is permitted within the boundaries of a single (compound) statement terminated horizontally by a period. The reference manual for the basic system is printed on two sides of a plastic 8 1/4 by 10 3/4 inch sheet which is illustrated in appendix C. The philosophy of the system is to permit the user to exercise a variety of (sometimes equivalent) syntactical forms identical to ordinary mathematical notation, to allow easy input even by awkward typists, and to minimize the amount of procedural and linguistic detail necessary for use of the system. Ambigious input is resolved by the use of context dependent processing and, prior to full compilation and execution, by output to the user of a Fortran-like linear interpretation of his input. The user can then correct or edit his program if the system's interpretation differs from his own.

However, as has been previously noted (1,3,7), experiments to test the relative efficiency of programming languages are difficult to carry out for several reasons. Long term studies on professional programmers engaged in producing a large production program present administrative difficulties, since the interests of those responsible for producing the program (e.g. minimizing costs) are not necessarily the same as those who are interested in studying the project in ways that assure statistical validity. Also, having another group duplicate the program using a different language is nearly always not practical. Shorter studies on artificial test problems tend to produce results of dubious statistical validity. This stems from the difficulty in controlling the human factors than can affect the results of such an experiment, the small number of subjects usually available, but most importantly the tremendously large variance or range in performance from one individual to another (1,3,5). My own personal experience in directing a computing center for many years and in managing programming efforts has led me to believe that a gifted programmer can produce checked-out code (regardless of the programming language) at a rate which appears to be 10 to 100 times faster than a programmer who is competent but of mediocre talent.

Because of these considerations it was decided to carry out some initial studies on a population consisting of students who were taking a first computing course using FORTRAN as a programming language. It could be expected that such a group would be relatively homogeneous in terms of education, work experience, and previous knowledge of computing. Also, the experimental procedures would be easier to administer if the instructor of the course agreed to cooperate and if the students were told that their participation in the experiment would be credited toward their work. However, the requirement that the experiment not interfere unduly with the normal curriculum of the course forced the use of test problems of minimal expectation effort to be assigned to that phase where the two languages were compared (Experiment II). Further, as a desireable side effect, it might be expected that the use of these very simple problems might narrow down the variance associated with natural programming ability. Also, in order to gain some feeling for the inherent variability of the results for less artificial problems, a separate study (Experiment I) was undertaken.

EXPERIMENT I (Fortran Timing)

PURPOSE

The purpose of this experiment was to gather performance (time) data for students learning FORTRAN.

METHOD

The subjects were students in a first level graduate computing course. There was no interference with the normal conduct of the course and students were asked only to supply time data for programming, debugging, keypunching, wait time, and number of debugging runs. The Fortran text was by McCracken (2) and problems were those picked by the instructor without regard to the purpose of this data sampling.

RESULTS

The detailed results of this experiment are given in Appendix A. The set of results for each assigned problem is first identified by the heading "Fortran Timing Results", followed by the problem number and page where it may be found in McCracken's book. The number of student responses for each problem is also given. The first block is the raw input data specifying programming time, keypunch time, the number of debug runs, debug time, debug keypunch time, and computer wait time, as reported by each student. Where no data was reported for any item, the code 9191 was entered at the appropriate place. The next block gives the statistical results computed from the raw data. In cases where data was not reported for either programming time or debug time for a specific problem and student then the sum of the average programming time plus average debug time might differ from the average of total (programming plus debug) time since total programming was not defined unless both items were reported together.

In the next output block, the average, range (difference between maximum and minimum), performance ratio (maximum divided by minimum, where a line of asteriks indicates that the ratio was in excess of a meaningful value), variance, and standard deviation associated with each measured category are given.

The last output block for each problem is a distribution plot of total programming time for the set of students. In each plot the vertical line labeled M denotes the median point and the vertical line labeled A denotes the point which represents the average total programming time for the particular problem.

The actual problems are given in Appendix D. There, McCracken's problems are shown side by side with the corresponding K-M programs which are solutions to McCracken's problems. The purpose of this appendix is to illustrate how little translation is necessary to go from the problem statement stage to the actual 2-D programs. It should also be pointed out that anyone with elementary mathematical literacy should be able to understand the K-M programs without prior instruction. The only artifices that might require referral to the K-M reference manual (Appendix C) might be the DIMENSION declaration (but whose meaning would be obvious to anyone with experience in any other programming language) and the use of the "ket" brackets following a variable to enclose the number representing the field size of the integer to be printed.

DISCUSSION

The results of this experiment make clear that there is a wide variation in individual programming performance. This is consistent with previously reported results (3). For meaningful sample size, the performance ratio associated with the measure of total programming time varied from a low of 10 to a high of 50 over the set of problems. For a category such as debug time, it was difficult to assign a meaningful performance ratio since this could vary from zero to relatively large quotients. Even the performance ratio associated with keypunch time seemed to be dependent on the particular problem. This might indicate that a certain portion of what was reported as keypunch time was not just the timing of mechanical effort but might include "think time" connected with each problem.

Furthermore, the distribution of these results tend to be highly skewed with large variances. The asymmetric nature of each distribution of total programming time is indicated by the relative separation between average and median on each plot. If should be noted that each distribution was plotted on a relative scale which was a function of the maximum element in the set, i.e., the maximum element always occurs on the extreme right of the plot.

But it is indeed surprising that such wide performance variations appear for such elementary problems and in a novice population with an expectation of relative homogeneity. Previous results suggest that these wide variations are also consistent with the performance of experienced programmers (1,3,6).

An important question to be addressed is whether such results are unique to programming or are they typical of performance in other technical or professional fields? It is difficult to think of another field which both allows the formation of a metric of quantitative performance and for which there is typically a wide range of performance. The only endeavors which come to mind that are characterized by analogous or even a greater range in quantitative performance are those of invention or scientific discovery. However, it would appear that the quality of intellectual endeavor associated with invention or scientific discovery is of a much higher plane than the mundane task of programming. Or, indeed is this really so?

The problem of the great variance in performance for invention and scientific discovery was examined by Shockley (6). Even in a highly selected population sample of research workers in scientific laboratories, he found that some individuals were at least fifty times more productive than others in equivalent circumstances.

Shockley speculated that these statistics might be explained by a model of human intelligence where each individual had a capability of being able to be aware of M ideas and their relationships simultaneously. Furthermore, since a higher value of M would allow many more permutations and combinations of basic ideas, then a relatively small increment in the value of M would cause a disproportionally larger increase in the total number of permuted or combined basic ideas relevant to an invention or intellectual discovery. An alternate model, also proposed by Shockley, would link intellectual productivity to the product of independently varying different factors. If the number of factors were large, and if one individual's factors each exceed that of another individual by a modest amount, the overall product of factors will be very different between the two individuals. Shockley also gives some hints as to how one can determine the parameters of each model (e.g., the value of "M") by studying the statistics of productivity.

For the case of programming, where one must keep in mind many considerations, Shockley's first model seems attractive. In fact, based on personal introspection, and informal discussions with other individuals as to how they function in the process of programming, it would appear that the capability of perceiving several ideas and their relationships simultaneously may be crucial to successful, efficient programming.

There are other ways of regarding these results. We could conclude that we must be more selective in training and employing programmers, since those programmers who do less well than the median exert a highly disproportionate negative effect on programming performance. But in view of the current shortage of programmers, this does not appear to be a practical alternative, even if one were to agree on an efficient selection criteria.

However, it does provide a clue as to why very large programming teams tend to be slower in producing a programming product than a highly selected tiny group. The overall performance of a group tends to be lower than its most inefficient member.

But one can treat this matter from a more disparate point of view. Put bluntly, it would appear that the results suggest that most people who do programming simply do not possess the special intellectual skills to easily program on an appropriately competant level. If one wishes to speculate within the framework of such a model, then it would appear that much of the present concern with program errors and program reliability may be missing the essense of the phenomenon. Instead of these errors being evidence of inadequate system methodology (e.g. an inadequate program structure), they may indeed point to essentially random psychological effects brought about by an inability to perform to the level of the programming task.

Regardless of the precise theoretical model to account for this wide variation in performance, it would seem that the nature of the phenomenon dictates the most efficient solution, i.e., automatic programming systems for that (large) part of programming tasks which are well formulated in some sense and where the translation from problem statement to computer code is essentially deterministic.

EXPERIMENT II (2-D vs Fortran)

PURPOSE

The purpose was to measure the comparative performance of programming novices, with some experience in FORTRAN, upon brief exposure to a 2-D language.

METHOD

Two very simple problems were chosen so as not to interfere with the usual classroom objectives. Problem #1 was:

" Print Y for values of X starting at X = 0.1 increasing in steps of 0.2 until X = 0.9 where

$$Y = \sum_{i=1}^{5} iX^{i} \text{ "}$$

and problem #2 was:

$$P = \frac{100 + 50X+25X^2}{\sqrt{10\ X^3 + 2X^4}}$$

Print P for X = 1, 2, ..., 6."

The experiment was repeated for two different classes taking a graduate first course offering in computer science where FORTRAN was introduced as a programming language. At the time the students were asked to participate in the experiment, they had already had approximately 20 to 23 hours of formal classroom instruction in elementary computing using FORTRAN. Also, in the preceding 10 weeks, they had had the opportunity of solving problems using FORTRAN. The formal lecture on the 2-D language was approximately one hour long. Also, they were given a copy of the one-sheet user manual for the language and a set of 16 sample problems illustrating 2-D programs, the initial computer conversion to a linear program format, the output of the automatic translation phase into FORTRAN, data input and the output results. Students were advised that they should not spend more than two hours looking over this "take home" material before attempting the problem. Thus, in terms of formal training and practice, the students had a background favoring FORTRAN competency by a factor of at least 20 to 1. Of course, we are not unmindful that there is a transfer learning effect from one language to another, but this requires study under an experiment of different design. None-the-less, it appears unlikely that, for the case of a novice population, the transfer learning effect would be so large as to diminish significantly the large bias of the experiment toward FORTRAN competancy. Put another way, any significant difference between the 2-D language and FORTRAN, if expressed as a performance ratio, should be multiplied by a "handicap" factor. This factor should have a magnitude lying somewhere between 1 and 20.

Each class was randomly divided into two equal groups. Group I was assigned problem #1 to be done in FORTRAN and Problem #2 to be done in K-M. Group II was assigned Problem #1 to be done in K-M and Problem #2 to be done in FORTRAN. The completed FORTRAN problems were required to be returned two weeks later. Since there were not sufficient terminals available for the class to input the K-M programs directly, within the given time limitations, they were asked to return their hand-written K-M programs one week later at the beginning of the class. These programs were visually inspected for correctness, and, where needed, error message output was simulated and returned to the students for further debugging. Final hand-written K-M programs were returned by the students one week later. The use of hand-written program input is not unusual with K-M systems practice. At Columbia University's Hudson Laboratories, where the K-M system was used as a production system (1) for several years, users were given the option of either typing their programs directly for online (or offline) processing or having their programs typed by the typists employed in the computing center and processed offline. Our experience at Columbia indicated that the effort and error rate involved in typing K-M programs were no greater than that involved in the equivalent typing of mathematical text using a standard office typewriter. We also concluded that the input typing error rate for the K-M program was substantially less than the error rate experienced in keypunching the equivalent FORTRAN program. Our experience, then, led us to believe that, in a practical sense, the K-M language was more suitable than FORTRAN, to a computing center environment which tried to convenience users by accepting hand written input for program compilation. However, we should note that these conclusions were based on our informal observations and no formal experiments were made to obtain a precise measure of these comparisons.

RESULTS

Since a few of the final programs were still flawed by major or minor errors, an additional weighted data set for each class was processed to reflect these errors. The weighting was as follows: If the program was incorrect, then 50% of the programming time was added to the debug time, the sum being treated as the weighted debug time. If the program contained a minor or trivial error then 20% of the programming time was added to the debug time, the sum being treated as the weighted debug time. However, the results of these weighted sets were not substantially different from the unweighted data sets.

The results of this experiment are given in Appendix B. The block labeled as Set #l first gives the raw data reported by the class of 20 students for K-M programming time, K-M debug time, FORTRAN programming time, and FORTRAN debug time. Data for FORTRAN keypunch time, number of debug runs, debug keypunch time, and wait time are also reported but were not processed at this time.

Following the raw data, the total programming time (programming time + debug time) is arranged as a two-by-two cellular array, where the elements of each cell list total programming time corresponding to problem number and language.

For problem 1, the mean (total) programming time ratio (R_t^{FK}) of FORTRAN vs K-M is 3.6 and for problem 2 the FORTRAN vs K-M time ratio is 2.9. The corresponding unbiased estimates of the standard deviations are given and are typically very large for each datum. As we have noted previously, these ratios should be multiplied by a "handicap" factor h, where $1<h<20$, to give a truer picture of the performance of one language relative to the other. Thus if we define economic efficiency (E) to be inversely proportional to total programming time, then the economic efficiency of K-M vs FORTRAN as a function of problem would be

$$E_{KF} = hR_t^{FK} .$$

An analysis of variance indicates that the difference between the two languages is significant at the $\varepsilon = .05$ level, and that the difference between the two problems is not significant at the $\varepsilon = .05$ level but may be considered significant at the $\varepsilon = .1$ level.

The results for the weighted set 1 are not dramatically different. For problem 1, $R_t^{FK} = 3.96$ and for problem 2, $R_t^{FK} = 3.7$. The analysis of variance indicates that the difference between the two languages is significant at the $\varepsilon = .05$ level and that the difference between the two problems is not significant. The main effect of the weighting was to increase the FORTRAN vs K-M programming time ratio for problem 2 and to also increase the relative variances, accounting for the lessened statistical significance of the results.

The results of set #2 are based on a much larger sample than that used in Set #1 (34 students compared to 20 in the previous sample). For problem #1, the mean (total) programming time ratio of FORTRAN vs K-M is R_t^{FK} = 6.4. For problem 2, R_t^{FK} = 1.76. In each case the economic efficiency of K-M vs FORTRAN is given by $E_{KF} = hR_t^{FK}$, $1<h<20$.

The analysis of variance for this set indicates that the difference between the two languages is significant at the $\varepsilon = .001$ level and that the difference between the two problems is significant at the $\varepsilon = .05$ level. Also, there is a non-neglible interaction between problem type and language.

For the weighted set #2, $R_t^{FK} = 7.1$ for problem 1, $R_t^{FK} = 1.76$ for problem 2. The analysis of variance indicates that the difference between the two languages is significant at the $\varepsilon = .005$ level and that the difference between the two problems is significant at the $\varepsilon = .05$ level.

DISCUSSION

These experiments offer clear evidence that there is a decided economic advantage for novices in using a two-dimensional approach to scientific/engineering application programming. There is reason to believe that the relative advantage of the 2-D approach becomes even greater when used in a production environment for complex application programs (1). One of the several reasons for this is that the 2-D programming approach models exactly in many cases, or very closely in the remaining cases, visually complex mathematical formula. Therefore, a certain part of the dubugging task simplifies to routine proof reading of the original problem formulae contrasted to the 2-D program statements. Thus there is a marked reduction of program error for complex formulae representation due to the fact that the translation from problem to program is either identical or characterized by minimal change. The same philosophy applies to the syntax of input-output which is a major source of program error in such languages as FORTRAN. The K-M language uses free-field and type-independent input and several kinds of output forms, both linear and two-dimensional, so that checking output syntax as a function of problem specification is also reduced to a proof reading task (see Appendices C and E for some examples).

However, the process of making precise objective judgements of relative language efficiency confronts many difficult problems of experimental design and practical implementation due to the large range of individual programming capability. Judgement of precise 2-D programming efficiency is particularly difficult because of its novel programming approach, the relative unavailability of suitable input terminals, and the artificial intelligence aspects of the system design for a 2-D effective system. None-the-less, the relative economic efficiency factor of a 2-D language such as K-M when compared to a linear programming language such as FORTRAN, appears to be so large that only an order of magnitude best estimate seems to be sufficient. This best estimate is expressed above by the term E_{KF}. Certainly, further experimentation along these lines is appropriate to obtain best estimates within a narrower range.

ACKNOWLEDGEMENTS

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REFERENCES

(1) M. Klerer, The economics, politics, and sociology of two-dimensional systems ACM-SIGPLAN NOTICES, vol. 7, no. 10, October 1972.

(2) D.D. McCracken, A Guide To Fortran IV Programming, 2nd edition, John Wiley, 1972.

(3) H. Sackman, Man-Computer Problem Solving, Auerbach, 1970.

(4) J.E. Sammet, Programming Languages, Prentice-Hall, 1969.

(5) B. Shneiderman, et al, Experimental investigations of the utility of detailed flowcharts in programming, CACM, vol. 20, no. 6, June 1977.

(6) W. Shockley, On the Statistics of Individual Variations of Productivity in Research Laboratories, Proceeding of the IRE, March, 1957, pp. 279-290.

(7) G.M. Weinberg, The Psychology of Computer Programming, Van Nostrand Reinhold, 1971.

APPENDIX A

FORTRAN TIMING RESULTS

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FORTRAN TIMING RESULTS

PROBLEM # 14 PAGE 195

NUMBER OF STUDENTS=  2

        NOTE THAT ALL TIME INFORMATION IS IN SECONDS
            (1)            (2)        (3)        (4)        (5)     (6)

STUDENT PROGRAMMING KEYPUNCH  DEBUG       DEBUG      DEBUG    WAIT
  ID        TIME           TIME   RUNS        TIME     KEYPUNCH  TIME
                                                         TIME

   8.       1800.          900.     3.        1800.       900.  1800.
  25.       1500.         1200.     2.        3600.       300.   600.

NOTE THAT THE NUMBER 9191 IS A CODE TO SIGNIFY
THAT NO DATA SUPPLIED FOR THIS INSTANCE

            STATISTICAL RESULTS

NOTE THAT TOTAL PROGRAMMING TIME IS NOT
DEFINED IF THERE IS NO DATA FOR EITHER
PROGRAMMING TIME OR FOR DEBUGGING TIME

AVERAGE PROGRAMMING TIME =  1650. SECONDS
AVERAGE DEBUG TIME =  2700. SECONDS

AVERAGE PROGRAMMING TIME + AVERAGE DEBUG TIME =  4350. SECONDS


                        AVERAGE  RANGE PERFORMANCE  VARIANCE STANDARD
                                           RATIO              DEVIATION
PROGRAMMING TIME          1650.     300.     1.2     0.45000E 05     212.
KEYPUNCH TIME             1050.     300.     1.3     0.45000E 05     212.
DEBUG RUNS                   3.       1.     1.5     0.50000E 00       1.
DEBUG TIME                2700.    1800.     2.0     0.16200E 07    1273.
DEBUG KEYPUNCH TIME        600.     600.     3.0     0.18000E 06     424.
WAIT TIME                 1200.    1200.     3.0     0.72000E 06     849.
TOT(PROG+DEBUG)TIME       4350.    1500.     1.4     0.11250E 07    1061.

NOTE THAT ALL TIMES ARE IN SECONDS

NOTE THAT IF THE MINIMUM DATA ELEMENT IS 0, THEN ONLY
IN THE CALCULATION FOR PERFORMANCE RATIO THE 0 IN THE
DENOMINATOR IS REPLACED BY 1

DISTRIBUTION OF TOTAL PROGRAMMING TIME

-------------------------------------------------*--------------------*
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FORTRAN TIMING RESULTS

PROBLEM # 5 PAGE 19

NUMBER OF STUDENTS= 24

        NOTE THAT ALL TIME INFORMATION IS IN SECONDS
            (1)           (2)      (3)        (4)        (5)     (6)

STUDENT PROGRAMMING KEYPUNCH  DEBUG       DEBUG      DEBUG     WAIT
  ID        TIME        TIME  RUNS        TIME      KEYPUNCH  TIME
                                                      TIME

  1.       1800.       1800.    1.          300.          0.  1200.
  2.        600.        300.    2.          600.       1200.  4800.
  3.       1020.       1200.    0.            0.          0.  1200.
  4.        900.       2100.    1.          600.       2700.  8100.
  5.       4200.       7500.    1.          300.        120.   900.
  6.       2700.       3900.    3.         5400.       5400.  2700.
  7.       1500.       3600.    3.         3600.       4200.  4500.
  8.        300.        600.    0.            0.          0.  7200.
  9.       1800.       2100.    2.          900.        900.  1800.
 10.        300.        600.    0.            0.          0.  1500.
 11.       2280.       1200.    0.            0.          0.   600.
 12.        300.       1800.    0.            0.          0.   900.
 13.        900.        900.    2.         2100.        300.  6000.
 14.       4200.       7200.    3.        10800.      15000. 10800.
 15.       1800.       3600.    1.         1200.       1500.  1800.
 16.        300.       1020.    1.          300.         60.  1200.
 17.       1800.       5400.    2.         2400.       1200.  3600.
 18.       5100.       3900.    1.          900.        600.   300.
 19.       1800.       3600.    2.         2700.       3600.  5400.
 20.       1200.       2700.    3.         1200.        600.  1800.
 21.       1800.       3600.    1.          900.       1800.  1680.
 22.       2100.       2100.    0.            0.          0.   900.
 23.        900.       1800.    3.         2700.       1800.   600.
 24.       1500.       2400.    2.          900.       1200.  2100.

NOTE THAT THE NUMBER 9191 IS A CODE TO SIGNIFY
THAT NO DATA SUPPLIED FOR THIS INSTANCE

           STATISTICAL RESULTS

NOTE THAT TOTAL PROGRAMMING TIME IS NOT
DEFINED IF THERE IS NO DATA FOR EITHER
PROGRAMMING TIME OR FOR DEBUGGING TIME

AVERAGE PROGRAMMING TIME =  1713. SECONDS
AVERAGE DEBUG TIME =  1575. SECONDS

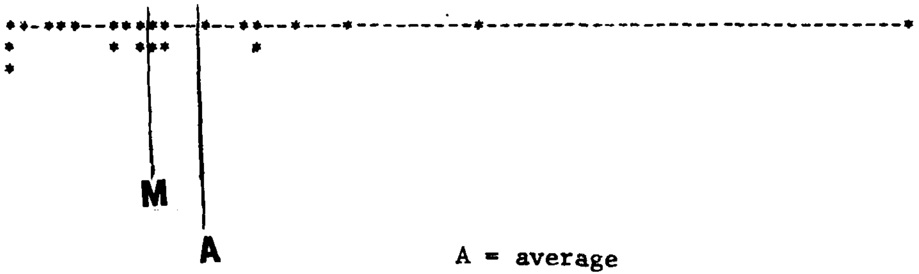
AVERAGE PROGRAMMING TIME + AVERAGE DEBUG TIME =  3288. SECONDS


                        AVERAGE  RANGE PERFORMANCE  VARIANCE STANDARD
                                           RATIO              DEVIATION
PROGRAMMING TIME          1713.   4800.   17.0    0.15573E 07   1248.
KEYPUNCH TIME             2705.   7200.   25.0    0.35601E 07   1887.
DEBUG RUNS                  1.      3.     3.0    0.11597E 01     1.
DEBUG TIME                1575.  10800.  *****    0.54619E 07   2337.
DEBUG KEYPUNCH TIME       1758.  15000.  *****    0.96919E 07   3113.
WAIT TIME                 2983.  10500.   36.0    0.73360E 07   2709.
TOT(PROG+DEBUG)TIME       3288.  14700.   50.0    0.94922E 07   3081.
```

```
NOTE THAT ALL TIMES ARE IN SECONDS

NOTE THAT IF THE MINIMUM DATA ELEMENT IS 0, THEN ONLY
IN THE CALCULATION FOR PERFORMANCE RATIO THE 0 IN THE
DENOMINATOR IS REPLACED BY 1

DISTRIBUTION OF TOTAL PROGRAMMING TIME
```



A = average
M = median

```
FORTRAN TIMING RESULTS

PROBLEM # 8 PAGE 19

NUMBER OF STUDENTS= 24

       NOTE THAT ALL TIME INFORMATION IS IN SECONDS
             (1)            (2)       (3)        (4)        (5)     (6)

STUDENT PROGRAMMING KEYPUNCH  DEBUG       DEBUG       DEBUG    WAIT
  ID        TIME        TIME  RUNS        TIME      KEYPUNCH  TIME
                                                      TIME

   1.        900.        600.     1.         60.       180.  1200.
   2.        600.        900.     2.        600.      1200.  4800.
   3.       2220.       1500.     0.          0.         0.  1200.
   4.       1800.       2400.     1.        600.        60.  4200.
   5.       2700.       5400.     0.          0.         0.   600.
   6.       3600.       4500.     2.       3000.      4800.  2700.
   7.       1200.       3600.     2.       2700.      4200.  2400.
   8.        300.        480.     0.          0.         0.  7200.
   9.       2100.       1800.     2.        900.       900.  1800.
  10.        420.        900.     1.        300.       180.  1200.
  11.       3000.       1320.     0.          0.         0.  1200.
  12.        300.       1800.     0.          0.         0.   900.
  13.        600.        900.     1.        300.       120.  1500.
  14.       3600.       4500.     2.       7800.      3600.  3600.
  15.       2700.       4500.     0.          0.         0.  1800.
  16.        540.       1200.     0.          0.         0.  1800.
  17.       1800.       5400.     2.       1200.       600.  3600.
  18.       2100.       1500.     0.          0.         0.   300.
  19.       3600.       3600.     1.        900.       900.  1800.
  20.        900.       2700.     2.        900.       600.   900.
  21.       1200.       2400.     3.       4800.       900.  2040.
  22.       2700.       2700.     1.       1200.       300.  1800.
  23.        900.        900.  9191.       3600.      1800.   600.
  24.       1800.       2100.     2.       1200.       900.  2400.

NOTE THAT THE NUMBER 9191 IS A CODE TO SIGNIFY
THAT NO DATA SUPPLIED FOR THIS INSTANCE

          STATISTICAL RESULTS

NOTE THAT TOTAL PROGRAMMING TIME IS NOT
DEFINED IF THERE IS NO DATA FOR EITHER
PROGRAMMING TIME OR FOR DEBUGGING TIME

AVERAGE PROGRAMMING TIME =  1733. SECONDS
AVERAGE DEBUG TIME =  1253. SECONDS

AVERAGE PROGRAMMING TIME + AVERAGE DEBUG TIME =  2985. SECONDS


                        AVERAGE  RANGE PERFORMANCE  VARIANCE STANDARD
                                          RATIO               DEVIATION
PROGRAMMING TIME          1733.   3300.    12.0    0.11608E 07    1077.
KEYPUNCH TIME             2400.   4920.    11.3    0.23022E 07    1517.
DEBUG RUNS                  1.      3.      3.0    0.86201E 00       1.
DEBUG TIME                1253.   7800.   *****    0.34639E 07    1861.
DEBUG KEYPUNCH TIME        885.   4800.   *****    0.18190E 07    1349.
WAIT TIME                 2148.   6900.    24.0    0.23904E 07    1546.
TOT(PROG+DEBUG)TIME       2985.  11100.    33.0    0.58198E 07    2412.
```

```
NOTE THAT ALL TIMES ARE IN SECONDS

NOTE THAT IF THE MINIMUM DATA ELEMENT IS 0, THEN ONLY
IN THE CALCULATION FOR PERFORMANCE RATIO THE 0 IN THE
DENOMINATOR IS REPLACED BY 1

DISTRIBUTION OF TOTAL PROGRAMMING TIME
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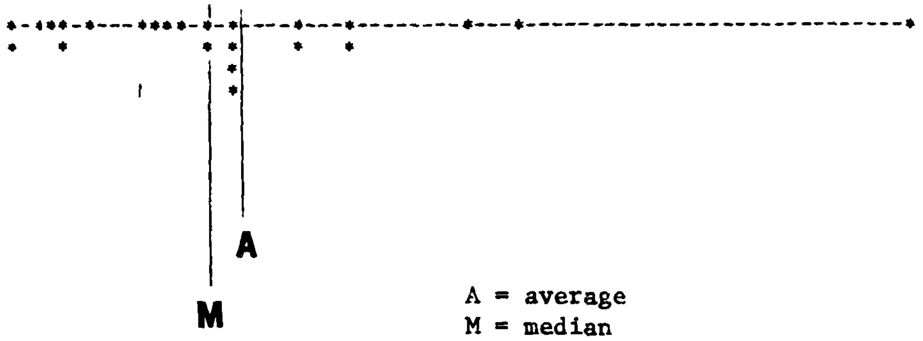

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FORTRAN TIMING RESULTS

PROBLEM # 4 PAGE 39 HWK 5

NUMBER OF STUDENTS=  2

       NOTE THAT ALL TIME INFORMATION IS IN SECONDS
           (1)            (2)       (3)       (4)        (5)     (6)

STUDENT PROGRAMMING KEYPUNCH  DEBUG       DEBUG        DEBUG     WAIT
  ID        TIME          TIME    RUNS        TIME       KEYPUNCH  TIME
                                                           TIME

  7.        2400.          2400.     2.        2400.       3000.  1800.
  5.        1800.           600.     0.           0.          0.   300.

NOTE THAT THE NUMBER 9191 IS A CODE TO SIGNIFY
THAT NO DATA SUPPLIED FOR THIS INSTANCE

          STATISTICAL RESULTS

NOTE THAT TOTAL PROGRAMMING TIME IS NOT
DEFINED IF THERE IS NO DATA FOR EITHER
PROGRAMMING TIME OR FOR DEBUGGING TIME

AVERAGE PROGRAMMING TIME =  2100. SECONDS
AVERAGE DEBUG TIME =  1200. SECONDS

AVERAGE PROGRAMMING TIME + AVERAGE DEBUG TIME =  3300. SECONDS


                    AVERAGE  RANGE PERFORMANCE  VARIANCE STANDARD
                                    RATIO                DEVIATION
PROGRAMMING TIME      2100.    600.    1.3     0.18000E 06     424.
KEYPUNCH TIME         1500.   1800.    4.0     0.16200E 07    1273.
DEBUG RUNS              1.       2.    2.0     0.20000E 01      1.
DEBUG TIME            1200.   2400.  *****     0.28800E 07    1697.
DEBUG KEYPUNCH TIME   1500.   3000.  *****     0.45000E 07    2121.
WAIT TIME             1050.   1500.    6.0     0.11250E 07    1061.
TOT(PROG+DEBUG)TIME   3300.   3000.    2.7     0.45000E 07    2121.

NOTE THAT ALL TIMES ARE IN SECONDS

NOTE THAT IF THE MINIMUM DATA ELEMENT IS 0, THEN ONLY
IN THE CALCULATION FOR PERFORMANCE RATIO THE 0 IN THE
DENOMINATOR IS REPLACED BY 1

DISTRIBUTION OF TOTAL PROGRAMMING TIME

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FORTRAN TIMING RESULTS

PROBLEM # 13 PAGE 90 HWK 5(CH 4)

NUMBER OF STUDENTS= 16

       NOTE THAT ALL TIME INFORMATION IS IN SECONDS
            (1)           (2)       (3)        (4)         (5)     (6)

STUDENT PROGRAMMING KEYPUNCH  DEBUG       DEBUG       DEBUG    WAIT
  ID        TIME         TIME   RUNS        TIME      KEYPUNCH  TIME
                                                        TIME

   8.        600.         900.      2.         600.       300.   600.
   6.       7800.        4200.      4.         900.      7800.  3900.
   7.       1800.        1800.      2.        1800.      2400.  1500.
  21.       4500.        2700.      3.        6300.      1800.  5400.
  16.       1800.        1800.      3.        1500.       900.  3600.
  15.       3600.        3600.      1.        4500.       900.  5400.
  12.       1200.        2700.      0.           0.         0.  2700.
  17.       3600.        3600.      1.        1800.       900.  1800.
  22.       4800.        1500.      1.         900.       600.  6000.
  25.       1800.        1200.      1.         600.       300.   600.
  26.        600.        1200.      2.         360.       300.  1200.
  18.       9000.        3600.      1.         600.       600.   300.
   3.       5400.        2700.      8.       13800.      3000.  9000.
  24.       2700.        1800.      4.        3000.      2400.  1800.
  23.       3600.        2700.      5.        3600.      3600.  3600.
   1.       3600.        3600.      2.        3600.      3600.  1800.

NOTE THAT THE NUMBER 9191 IS A CODE TO SIGNIFY
THAT NO DATA SUPPLIED FOR THIS INSTANCE

           STATISTICAL RESULTS

NOTE THAT TOTAL PROGRAMMING TIME IS NOT
DEFINED IF THERE IS NO DATA FOR EITHER
PROGRAMMING TIME OR FOR DEBUGGING TIME

AVERAGE PROGRAMMING TIME =  3525. SECONDS
AVERAGE DEBUG TIME =  2741. SECONDS

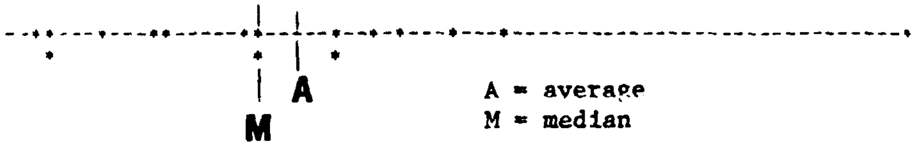
AVERAGE PROGRAMMING TIME + AVERAGE DEBUG TIME =  6266. SECONDS


                         AVERAGE  RANGE PERFORMANCE  VARIANCE STANDARD
                                            RATIO              DEVIATION
PROGRAMMING TIME          3525.   8400.    15.0    0.54056E 07    2325.
KEYPUNCH TIME             2475.   3300.     4.7    0.10181E 07    1009.
DEBUG RUNS                   3.      8.     8.0    0.37500E 01       2.
DEBUG TIME                2741.  13800.   *****    0.11039E 08    3323.
DEBUG KEYPUNCH TIME       1838.   7800.   *****    0.37448E 07    1935.
WAIT TIME                 3075.   8700.    30.0    0.54169E 07    2327.
TOT(PROG+DEBUG)TIME       6266.  18240.    20.0    0.20107E 08    4484.

NOTE THAT ALL TIMES ARE IN SECONDS

NOTE THAT IF THE MINIMUM DATA ELEMENT IS 0, THEN ONLY
IN THE CALCULATION FOR PERFORMANCE RATIO THE 0 IN THE
DENOMINATOR IS REPLACED BY 1

DISTRIBUTION OF TOTAL PROGRAMMING TIME
```



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FORTRAN TIMING RESULTS

PROBLEM # 13 PAGE 90 HWK 5

NUMBER OF STUDENTS= 16

       NOTE THAT ALL TIME INFORMATION IS IN SECONDS
           (1)             (2)        (3)        (4)         (5)      (6)

STUDENT PROGRAMMING KEYPUNCH  DEBUG       DEBUG       DEBUG     WAIT
  ID       TIME        TIME   RUNS        TIME       KEYPUNCH   TIME
                                                       TIME

   8.        900.        900.      3.         900.       300.    600.
   6.       7200.       3300.      3.        7800.      6300.   3600.
   7.       1500.       1500.      1.        1800.      1800.    600.
  21.       3600.       2100.      2.        3600.      1500.   3600.
  16.       2700.       2100.      5.        2400.      1200.   5400.
  12.       1800.       2700.      1.         600.         0.   1200.
  17.       1800.       3600.      1.         900.       900.   1800.
  22.       5700.       1740.      2.        1740.      1200.   7200.
  20.       2700.       1800.      5.        1800.      1800.   9191.
  25.       1800.       1200.      3.        3600.       900.   1500.
  26.        600.       1200.      1.          60.        60.    900.
  13.       3600.       2700.      5.        7200.      3600.   2400.
   3.       9000.       3000.      8.        4800.      3600.   9000.
  24.       1800.       1200.      3.        3000.      2400.   1200.
  23.       2700.       2700.      5.        3600.      3600.   3600.
   1.       3600.       3600.      4.        3600.      1800.   1800.

NOTE THAT THE NUMBER 9191 IS A CODE TO SIGNIFY
THAT NO DATA SUPPLIED FOR THIS INSTANCE

          STATISTICAL RESULTS

NOTE THAT TOTAL PROGRAMMING TIME IS NOT
DEFINED IF THERE IS NO DATA FOR EITHER
PROGRAMMING TIME OR FOR DEBUGGING TIME

AVERAGE PROGRAMMING TIME =  3188. SECONDS
AVERAGE DEBUG TIME =  2963. SECONDS

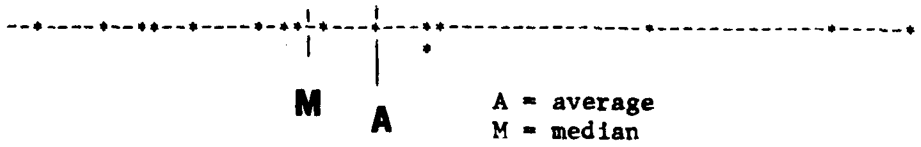
AVERAGE PROGRAMMING TIME + AVERAGE DEBUG TIME =  6150. SECONDS


                         AVERAGE  RANGE PERFORMANCE  VARIANCE STANDARD
                                           RATIO               DEVIATION
PROGRAMMING TIME          3188.   8400.    15.0    0.49936E 07   2235.
KEYPUNCH TIME             2209.   2700.     4.0    0.75565E 06    869.
DEBUG RUNS                   3.      7.     8.0    0.36875E 01      2.
DEBUG TIME                2963.   7740.   130.0    0.45868E 07   2142.
DEBUG KEYPUNCH TIME       1935.   6300.   *****    0.25616E 07   1601.
WAIT TIME                 2960.   8400.    15.0    0.58904E 07   2427.
TOT(PROG+DEBUG)TIME       6150.  14340.    22.7    0.15732E 08   3966.

NOTE THAT ALL TIMES ARE IN SECONDS

NOTE THAT IF THE MINIMUM DATA ELEMENT IS 0, THEN ONLY
IN THE CALCULATION FOR PERFORMANCE RATIO THE 0 IN THE
DENOMINATOR IS REPLACED BY 1

DISTRIBUTION OF TOTAL PROGRAMMING TIME
```



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FORTRAN TIMING RESULTS

PROBLEM # 3 PAGE 115 HWK 6(CH 5)

NUMBER OF STUDENTS= 18

       NOTE THAT ALL TIME INFORMATION IS IN SECONDS
           (1)            (2)      (3)         (4)         (5)    (6)

STUDENT PROGRAMMING KEYPUNCH  DEBUG       DEBUG       DEBUG   WAIT
  ID        TIME         TIME  RUNS        TIME      KEYPUNCH  TIME
                                                      TIME

  8.        900.          900.    3.          900.        600.  1800.
  6.       3600.         3300.    4.         6900.       3600.  3900.
  7.       1500.         1500.    3.         3000.       3000.  1800.
 21.       6300.         5700.    2.         5400.        600.  5400.
 16.       1200.          900.    2.         1500.        600.  4500.
 12.       1800.         2700.    0.            0.          0.  1800.
 15.       2700.         9191.    1.         1800.        900.  1800.
  4.       1500.         2100.    3.         1200.        600.  2400.
 22.       5400.         1980.    1.         1500.        900.  7200.
 20.        900.         2100.    2.         1500.        900.  9191.
 25.       1800.         1200.    4.         3600.       1200.  1800.
 26.       1200.         1500.    1.          600.        240.  1200.
 19.      14400.         5400.    3.         3600.       2700.   600.
 13.       1800.          900.    7.         8400.       1800.  4500.
  3.       3000.         1800.    6.        10200.       3600.  7200.
 24.       1800.         1200.    4.         2400.       2100.  1800.
 23.       3600.         3600.    6.         5400.       2700.  2700.
  1.       3600.         1800.    2.         3600.       2400.  1800.

NOTE THAT THE NUMBER 9191 IS A CODE TO SIGNIFY
THAT NO DATA SUPPLIED FOR THIS INSTANCE

          STATISTICAL RESULTS

NOTE THAT TOTAL PROGRAMMING TIME IS NOT
DEFINED IF THERE IS NO DATA FOR EITHER
PROGRAMMING TIME OR FOR DEBUGGING TIME

AVERAGE PROGRAMMING TIME =  3167. SECONDS
AVERAGE DEBUG TIME =  3417. SECONDS

AVERAGE PROGRAMMING TIME + AVERAGE DEBUG TIME =  6583. SECONDS

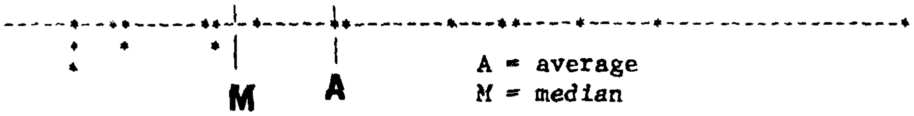


                        AVERAGE  RANGE PERFORMANCE 'VARIANCE STANDARD
                                          RATIO              DEVIATION
PROGRAMMING TIME          3167.  13500.   16.0     0.96022E 07   3099.
KEYPUNCH TIME             2269.   4800.    6.3     0.20157E 07   1420.
DEBUG RUNS                   3.      7.    7.0     0.34444E 01      2.
DEBUG TIME                3417.  10200.  *****     0.75914E 07   2755.
DEBUG KEYPUNCH TIME       1580.   3600.  *****     0.12968E 07   1139.
WAIT TIME                 3071.   6600.   12.0     0.38703E 07   1967.
TOT(PROG+DEBUG)TIME       6583.  16200.   10.0     0.20395E 08   4516.

NOTE THAT ALL TIMES ARE IN SECONDS

NOTE THAT IF THE MINIMUM DATA ELEMENT IS 0, THEN ONLY
IN THE CALCULATION FOR PERFORMANCE RATIO THE 0 IN THE
DENOMINATOR IS REPLACED BY 1

DISTRIBUTION OF TOTAL PROGRAMMING TIME
```



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FORTRAN TIMING RESULTS

PROBLEM # 9 PAGE 115 HWK 6(CH 5)

NUMBER OF STUDENTS= 16

        NOTE THAT ALL TIME INFORMATION IS IN SECONDS
            (1)            (2)       (3)        (4)         (5)     (6)

STUDENT PROGRAMMING KEYPUNCH  DEBUG       DEBUG       DEBUG    WAIT
  ID        TIME        TIME   RUNS        TIME      KEYPUNCH  TIME
                                                       TIME

   7.       1800.       1800.     4.       3000.       3000.  1800.
  21.       7200.       7800.     3.      10800.       2400. 10800.
  16.        600.       1200.     3.       1800.        900.  3600.
  12.       2100.       3000.     1.       1200.        600.  4500.
  15.       4200.       3600.     5.       7200.       5400.  7200.
   4.       1800.       3300.     4.       4200.       2400. 13800.
  22.       5280.       1920.     2.       2400.       1320.  8100.
  20.       1800.       3600.     3.       2700.       1200.  9191.
  25.       1800.       1200.     3.       5400.        900.  1800.
   8.        900.        900.     2.        600.        300.  1200.
   6.       8400.       4800.     4.       7800.       6900.  3900.
  26.        480.        900.     1.       9191.       9191.  1500.
   3.       6000.       5400.    15.       6600.       3600.  3600.
  24.       1500.       1800.     3.       1800.       1500.  1800.
  23.       3600.       3600.     6.       7200.       2700.  3600.
   1.       3600.       1800.     2.       3600.         60.  1800.

NOTE THAT THE NUMBER 9191 IS A CODE TO SIGNIFY
THAT NO DATA SUPPLIED FOR THIS INSTANCE

            STATISTICAL RESULTS

NOTE THAT TOTAL PROGRAMMING TIME IS NOT
DEFINED IF THERE IS NO DATA FOR EITHER
PROGRAMMING TIME OR FOR DEBUGGING TIME

AVERAGE PROGRAMMING TIME =  3191. SECONDS
AVERAGE DEBUG TIME =  4420. SECONDS

AVERAGE PROGRAMMING TIME + AVERAGE DEBUG TIME =  7611. SECONDS

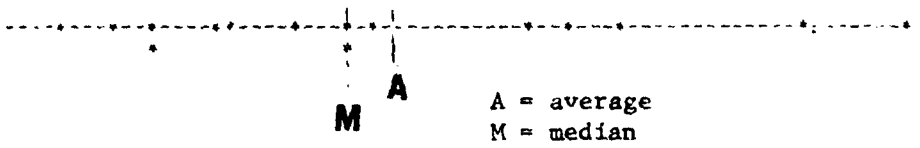


                         AVERAGE  RANGE PERFORMANCE  VARIANCE STANDARD
                                           RATIO              DEVIATION
PROGRAMMING TIME           3191.   7920.   17.5     0.54946E 07   2344.
KEYPUNCH TIME              2914.   6900.    8.7     0.33673E 07   1835.
DEBUG RUNS                   4.     14.    15.0     0.10027E 02      3.
DEBUG TIME                 4420.  10200.   18.0     0.81176E 07   2849.
DEBUG KEYPUNCH TIME        2212.   6840.  115.0     0.34435E 07   1856.
WAIT TIME                  4600.  12600.   11.5     0.13208E 08   3634.
TOT(PROG+DEBUG)TIME        7792.  16500.   12.0     0.23521E 08   4850.

NOTE THAT ALL TIMES ARE IN SECONDS

NOTE THAT IF THE MINIMUM DATA ELEMENT IS 0, THEN ONLY
IN THE CALCULATION FOR PERFORMANCE RATIO THE 0 IN THE
DENOMINATOR IS REPLACED BY 1

DISTRIBUTION OF TOTAL PROGRAMMING TIME
```



A = average
M = median

```
FORTRAN TIMING RESULTS

PROBLEM # 11 PAGE 115 HWK 6(CH 5)

NUMBER OF STUDENTS= 19

       NOTE THAT ALL TIME INFORMATION IS IN SECONDS
           (1)           (2)        (3)         (4)          (5)      (6)

STUDENT PROGRAMMING KEYPUNCH  DEBUG        DEBUG        DEBUG    WAIT
  ID        TIME        TIME   RUNS         TIME       KEYPUNCH  TIME
                                                         TIME

   8.       1800.         1800.      3.          1800.        900.  1800.
   6.       5400.         3000.      2.          3600.       5400.  3000.
   7.       1500.         1800.      4.          3000.       3000.  1200.
  21.       6600.         2400.      2.          4800.       1300.  7200.
   5.       4500.         3600.      3.          7800.        600.   300.
  16.       2100.         1800.      4.          2100.       1200.  5400.
  12.       4200.         3600.      1.          2100.       1200.  3000.
  15.       4800.         2400.      1.           600.        900.  1200.
  17.       3600.         3600.      2.          3600.       1800.  1800.
   4.       6600.         2700.      3.          1200.        900.  4200.
  22.       6300.         2100.      1.          1500.        900.  7200.
  20.       1200.         1800.      2.           600.       1200.  9191.
  25.       5700.         3300.      5.         14400.       1500.  2700.
  26.       1500.         1800.      2.           600.        480.  1200.
  18.      14400.         5400.      0.             0.          0.   300.
   3.       6300.         3600.     15.         10800.       4800.  7200.
  24.       3600.         2400.      4.          2700.       2400.  1800.
  23.       3600.         2700.      6.          5400.       2700.  3600.
   1.       3600.         3600.      2.          3600.       1800.  3000.

NOTE THAT THE NUMBER 9191 IS A CODE TO SIGNIFY
THAT NO DATA SUPPLIED FOR THIS INSTANCE

           STATISTICAL RESULTS

NOTE THAT TOTAL PROGRAMMING TIME IS NOT
DEFINED IF THERE IS NO DATA FOR EITHER
PROGRAMMING TIME OR FOR DEBUGGING TIME

AVERAGE PROGRAMMING TIME =  4595. SECONDS
AVERAGE DEBUG TIME =  3695. SECONDS

AVERAGE PROGRAMMING TIME + AVERAGE DEBUG TIME =  8289. SECONDS

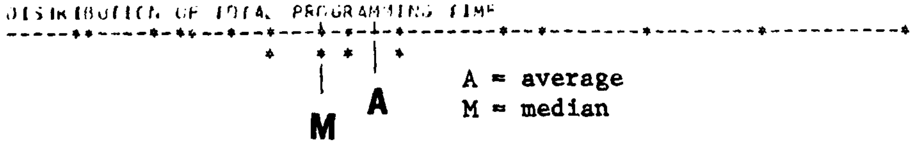


                        AVERAGE  RANGE PERFORMANCE  VARIANCE STANDARD
                                          RATIO               DEVIATION
PROGRAMMING TIME          4595.  13200.   12.0     0.84605E 07   2909.
KEYPUNCH TIME             2811.   3600.    3.0     0.85463E 06    924.
DEBUG RUNS                  3.     15.    15.0     0.97729E 01      3.
DEBUG TIME                3695.  14400.  *****     0.13140E 08   3625.
DEBUG KEYPUNCH TIME       1762.   5400.  *****     0.18618E 07   1364.
WAIT TIME                 3117.   6900.   24.0     0.49414E 07   2223.
TOT(PROG+DEBUG)TIME       8289.  18300.   11.2     0.22834E 08   4778.

NOTE THAT ALL TIMES ARE IN SECONDS

NOTE THAT IF THE MINIMUM DATA ELEMENT IS 0, THEN ONLY
IN THE CALCULATION FOR PERFORMANCE RATIO THE 0 IN THE

DISTRIBUTION OF TOTAL PROGRAMMING TIME
```



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FORTRAN TIMING RESULTS

PROBLEM # 2 PAGE 194 HWK 8

NUMBER OF STUDENTS=  4

       NOTE THAT ALL TIME INFORMATION IS IN SECONDS
            (1)            (2)      (3)      (4)        (5)     (6)

STUDENT PROGRAMMING KEYPUNCH  DEBUG       DEBUG      DEBUG    WAIT
  ID        TIME        TIME   RUNS        TIME     KEYPUNCH  TIME
                                                      TIME

  8.        1200.       1200.     2.         900.       600.  1200.
 25.        2100.       1200.     3.        2400.       600.  1200.
 13.        1800.       1800.     0.           0.         0.   300.
  1.        1800.       1200.     1.         600.       120.   300.

NOTE THAT THE NUMBER 9191 IS A CODE TO SIGNIFY
THAT NO DATA SUPPLIED FOR THIS INSTANCE

          STATISTICAL RESULTS

NOTE THAT TOTAL PROGRAMMING TIME IS NOT
DEFINED IF THERE IS NO DATA FOR EITHER
PROGRAMMING TIME OR FOR DEBUGGING TIME

AVERAGE PROGRAMMING TIME =  1725. SECONDS
AVERAGE DEBUG TIME =   975. SECONDS

AVERAGE PROGRAMMING TIME + AVERAGE DEBUG TIME =  2700. SECONDS


                        AVERAGE  RANGE PERFORMANCE  VARIANCE STANDARD
                                          RATIO               DEVIATION
PROGRAMMING TIME         1725.     900.     1,8    0.10688E 06     327.
KEYPUNCH TIME            1350.     600.     1.5    0.67500E 05     260.
DEBUG RUNS                 2.       3.      3.0    0.12500E 01       1.
DEBUG TIME                975.    2400.   *****    0.78188E 06     884.
DEBUG KEYPUNCH TIME       330.     600.   600.0    0.74700E 05     273.
WAIT TIME                 750.     900.     4,0    0.20250E 06     450.
TOT(PROG+DEBUG)TIME      2700.    2700.     2.5    0.11250E 07    1061.

NOTE THAT ALL TIMES ARE IN SECONDS

NOTE THAT IF THE MINIMUM DATA ELEMENT IS 0, THEN ONLY
IN THE CALCULATION FOR PERFORMANCE RATIO THE 0 IN THE
DENOMINATOR IS REPLACED BY 1

DISTRIBUTION OF TOTAL PROGRAMMING TIME

------------------------------*-----*-----*---------------------------------*
```

```
FORTRAN TIMING RESULTS

PROBLEM # 2(B) PAGE 49 HWK 4

NUMBER OF STUDENTS= 18

        NOTE THAT ALL TIME INFORMATION IS IN SECONDS
          (1)            (2)      (3)       (4)         (5)     (6)

STUDENT PROGRAMMING KEYPUNCH  DEBUG       DEBUG       DEBUG    WAIT
  ID       TIME         TIME   RUNS        TIME      KEYPUNCH  TIME
                                                        TIME

   8.       900.         900.     2.         300.        60.   1800.
   6.      2400.        1800.     3.        6000.      4800.   2700.
   7.      1200.        1200.     2.        1800.      2400.    900.
  21.      1800.        2700.     1.        2400.       900.   3600.
  19.      3600.        2700.     2.        3600.      1800.   7200.
  12.       900.         900.     0.           0.         0.   1800.
  15.      2700.        2400.     2.        1800.       900.   1800.
  17.      3600.        3600.     3.        7200.      1800.   2700.
   4.      2400.        6000.     1.         600.       300.   6300.
  22.      2400.         900.     0.           0.         0.   3300.
  20.      1200.        1800.     4.        2700.      2700.   9191.
  25.      1800.        1200.     1.        1800.       300.    900.
  26.       480.         900.     1.         120.       120.   1200.
  18.      7200.        2400.     1.        1500.       900.    300.
   3.      3600.        1800.     2.        2400.      1200.   1500.
  24.      1500.        1500.     2.         900.       900.   1200.
  23.      2700.        2700.     4.        3600.      3600.   3600.
   1.      3600.        3600.     4.        3600.      3600.   3600.

NOTE THAT THE NUMBER 9191 IS A CODE TO SIGNIFY
THAT NO DATA SUPPLIED FOR THIS INSTANCE

           STATISTICAL RESULTS

NOTE THAT TOTAL PROGRAMMING TIME IS NOT
DEFINED IF THERE IS NO DATA FOR EITHER
PROGRAMMING TIME OR FOR DEBUGGING TIME

AVERAGE PROGRAMMING TIME =  2443. SECONDS
AVERAGE DEBUG TIME =  2240. SECONDS

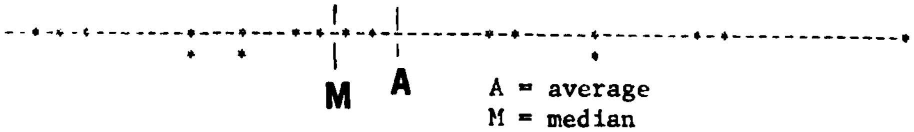
AVERAGE PROGRAMMING TIME + AVERAGE DEBUG TIME =  4683. SECONDS


                       AVERAGE  RANGE PERFORMANCE  VARIANCE STANDARD
                                        RATIO               DEVIATION
PROGRAMMING TIME         2443.   6720.   15.0    0.23079E 07   1519.
KEYPUNCH TIME            2167.   5100.    6.7    0.16056E 07   1267.
DEBUG RUNS                  2.      4.    4.0    0.14969E 01      1.
DEBUG TIME               2240.   7200.  *****    0.38032E 07   1950.
DEBUG KEYPUNCH TIME      1460.   4800.  *****    0.19444E 07   1394.
WAIT TIME                2612.   6900.   24.0    0.33222E 07   1823.
TOT(PROG+DEBUG)TIME      4683.  10200.   18.0    0.80914E 07   2845.

NOTE THAT ALL TIMES ARE IN SECONDS

NOTE THAT IF THE MINIMUM DATA ELEMENT IS 0, THEN ONLY
IN THE CALCULATION FOR PERFORMANCE RATIO THE 0 IN THE
DENOMINATOR IS REPLACED BY 1

DISTRIBUTION OF TOTAL PROGRAMMING TIME
```



A = average
M = median

```
FORTRAN TIMING RESULTS

PROBLEM # 2(E) PAGE 50 HWK 4

NUMBER OF STUDENTS= 19

        NOTE THAT ALL TIME INFORMATION IS IN SECONDS
              (1)           (2)      (3)       (4)         (5)      (6)

STUDENT PROGRAMMING KEYPUNCH  DEBUG       DEBUG        DEBUG     WAIT
  ID       TIME       TIME    RUNS        TIME       KEYPUNCH   TIME
                                                       TIME

   8.      1200.       900.     2.          60C.        300.    900.
   6.      3900.      2700.     3.         5400.       5400.   3000.
   7.      1200.      1200.     2.         1800.       2400.    900.
  21.      2700.      1500.     2.         1500.       1860.   1800.
  19.      3600.      2700.     2.         3600.       1800.   7200.
   5.      1800.       600.     0.            0.          0.    600.
  12.       900.      1200.     0.            0.          0.   1500.
  15.      1200.      2700.     1.          900.       1800.   1800.
  17.      3600.      3600.     4.        10800.       2700.   3600.
   4.      1500.      4800.     2.          600.        300.   3600.
  22.      2700.      1500.     0.            0.          0.   4200.
  20.      1200.      2700.     3.         1500.       1500.   9191.
  25.      150C.      1200.     1.         1800.        420.   1200.
  26.       900.       900.     1.          300.        300.   1500.
  18.      3600.      2400.     2.          900.       1800.   1800.
   3.      6600.      3000.     3.         1800.       1500.   1500.
  24.      1200.      1500.     1.          900.        600.    900.
  23.      2700.      3600.     5.         360C.       3600.   3600.
   1.      3600.      3600.     7.         3600.       3600.   3600.

NOTE THAT THE NUMBER 9191 IS A CODE TO SIGNIFY
THAT NO DATA SUPPLIED FOR THIS INSTANCE

           STATISTICAL RESULTS

NOTE THAT TOTAL PROGRAMMING TIME IS NOT
DEFINED IF THERE IS NO DATA FOR EITHER
PROGRAMMING TIME OR FOR DEBUGGING TIME

AVERAGE PROGRAMMING TIME =  2400. SECONDS
AVERAGE DEBUG TIME =  2084. SECONDS

AVERAGE PROGRAMMING TIME + AVERAGE DEBUG TIME =  4484. SECONDS

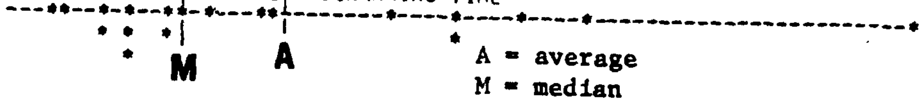

                        AVERAGE  RANGE PERFORMANCE  VARIANCE STANDARD
                                          RATIO              DEVIATION
PROGRAMMING TIME         2400.   5700.     7.3    0.20842E 07    1444.
KEYPUNCH TIME            2226.   4200.     8.0    0.13009E 07    1141.
DEBUG RUNS                 2.      7.      7.0    0.29751E 01      2.
DEBUG TIME               2084.  10800.   *****    0.62950E 07    2509.
DEBUG KEYPUNCH TIME      1573.   5400.   *****    0.20856E 07    1444.
WAIT TIME                2400.   6600.    12.0    0.26300E 07    1622.
TOT(PROG+DEBUG)TIME      4484.  13500.    16.0    0.11581E 08    3403.

NOTE THAT ALL TIMES ARE IN SECONDS

NOTE THAT IF THE MINIMUM DATA ELEMENT IS 0, THEN ONLY
IN THE CALCULATION FOR PERFORMANCE RATIO THE 0 IN THE

DENOMINATOR IS REPLACED BY 1

DISTRIBUTION OF TOTAL PROGRAMMING TIME
```



APPENDIX B

ANALYSIS OF VARIANCE RESULTS

```
SET#1

RAW DATA
COL.1=GROUP NUMBER  COL.2=STUDENT NUMBER WITHIN GROUP
COL.3=K-PROBLEM NUMBER  COL.4=K-PROGRAMMING TIME  COL.5=K-DEBUG TIME
COL.6=F-PROBLEM NUMBER  COL.7=F-PROGRAMMING TIME  COL.8=F-KEYPUNCH TIME
COL.9=NUMBER OF DEBUG RUNS  COL.10=F-DEBUG TIME  COL.11=DEBUG KEYPUNCH TIME
COL.12=WAIT TIME FOR RESULTS

(1)(2)(3)     (4)         (5)   (6)     (7)         (8)   (9)     (10)       (11)       (12)


 1  1  2       60.          0.  1       600.        600.  2      1800.       120.      2700.
 1  2  2       90.          0.  1       300.        240. '0         0.         0.      1200.
 1  3  2      900.          0.  1       660.        300.  0         0.         0.         0.
 1  4  2       60.          0.  1      3600.        600.  0         0.         0.         0.
 1  5  2      120.          0.  1      7200.       9191.  0         0.         0.         0.
 1  6  2      600.          0.  1      1200.       1200.  2       600.       600.      1800.
 1  7  2       25.         15.  1        60.       9191.  0         0.         0.         0.
 1  8  2       50.          0.  1       300.        300.  0         0.         0.      1800.
 1  9  2      120.        120.  1      1800.       1500.  0         0.         0.         0.
 1 10  2      240.          0.  1       900.        900.  0         0.         0.         0.
 2  1  1      150.          0.  2       300.        600.  0         0.         0.       600.
 2  2  1       90.          0.  2       420.       1200.  0         0.         0.       600.
 2  3  1      120.        120.  2       300.        300.  0         0.         0.       600.
 2  4  1      120.         60.  2       300.        180.  1        90.        60.      2700.
 2  5  1      240.         60.  2       480.        600.  0         0.         0.      1200.
 2  6  1      120.        120.  2       300.        600.  2       300.       300.      3600.
 2  7  1     1800.        900.  2      3600.       9191.  0         0.         0.         0.
 2  8  1      300.        300.  2       300.        600.  0         0.         0.         0.
 2  9  1      180.        300.  2       300.        180.  0         0.         0.      1500.
 2 10  1      180.        120.  2       300.        600.  0         0.         0.         0.

NUMBER OF STUDENTS= 20
DEVIDED EQUALLY INTO 2 GROUPS

ALL TIMES ARE IN SECONDS


THE DATA ELEMENT=9191. OR 91 SIGNIFIES THAT NO ACTUAL DATA SUPPLIED

TOTAL PROGRAMMING TIME (INCLUDES DEBUG TIME)

PROBLEM 1  K-LANGUAGE  F-LANGUAGE
                 150.       2400.
                  90.        300.
                 240.        660.
                 180.       3600.
                 300.       7200.
                 240.       1800.
                2700.         60.
                 600.        300.
                 480.       1800.
                 300.        900.

PROBLEM 2
                  60.        300.
                  90.        420.
                 900.        300.
                  60.        390.
                 120.        480.
                 600.        600.
                  40.       3600.
                  50.        300.
                 240.        300.
                 240.        300.
```

```
MEAN PROGRAMMING TIME (TOTAL) OF EACH PROBLEM-LANGUAGE COMBINATION

          K-LANGUAGE  F-LANGUAGE

PROBLEM 1       528.       1902.

PROBLEM 2       240.        699.

STANDARD DEVIATION (PROG. TIME) OF EACH PROBLEM LANGUAGE COMBINATION

          K-LANGUAGE  F-LANGUAGE

PROBLEM 1       738.       2057.

PROBLEM 2       273.        972.

S1=  0.1023557E 09

S2=  0.4442586E 08

S3=  0.3677510E 08

S4=  0.3393309E 08

S5=  0.2837539E 08

S6=TOTAL SUM OF SQUARES=  0.7398029E 08

S7=WITHIN-CELLS OF SQUARES=  0.5792982E 08

S8=ROWS SUMS OF SQUARES=  0.5557696E 07

S9=COLUMNS SUM OF SQUARES=  0.8399712E 07

S10=INTERACTION SUM OF SQUARES=  0.2093056E 07

MSWC=  0.1609161E 07

PROBLEM F(1,4(L-1))=  0.3453784E 01

LANGUAGE F(1,4(L-1))=  0.5219933E 01

4(L-1)=  0.3600000E 02
```

```
SET#1,(WEIGHTED DEBUG TIME, +50% INCORRECT PROGRAM, +20% MINOR ERROR)

RAW DATA
COL.1=GROUP NUMBER  COL.2=STUDENT NUMBER WITHIN GROUP
COL.3=K-PROBLEM NUMBER  COL.4=K-PROGRAMMING TIME  COL.5=K-DEBUG TIME
COL.6=F-PROBLEM NUMBER  COL.7=F-PROGRAMMING TIME  COL.8=F-KEYPUNCH TIME
COL.9=NUMBER OF DEBUG RUNS  COL.10=F-DEBUG TIME  COL.11=DEBUG KEYPUNCH TIME
COL.12=WAIT TIME FOR RESULTS

(1)(2)(3)     (4)          (5)   (6)     (7)          (8)   (9)     (10)         (11)         (12)


 1  1  2       60.          0.  1       600.         600.  2      1800.         120.        2700.
 1  2  2       90.          0.  1       300.         240.  0         0.           0.        1200.
 1  3  2      900.          0.  1       660.         300.  0       132.           0.           0.
 1  4  2       60.          0.  1      3600.         600.  0      1800.           0.           0.
 1  5  2      120.          0.  1      7200.        9191.  0      3600.           0.           0.
 1  6  2      600.          0.  1      1200.        1200.  2       600.         600.        1800.
 1  7  2       25.         15.  1        60.        9191.  0        30.           0.           0.
 1  8  2       50.          0.  1       300.         300.  0       150.           0.        1800.
 1  9  2      120.        144.  1      1800.        1500.  0         0.           0.           0.
 1 10  2      240.          0.  1       900.         900.  0         0.           0.           0.
 2  1  1      150.          0.  2       300.         600.  0         0.           0.         600.
 2  2  1       90.          0.  2       420.        1200.  0       210.           0.         600.
 2  3  1      120.        120.  2       300.         300.  0         0.           0.         600.
 2  4  1      120.         60.  2       300.         180.  1        90.          60.        2700.
 2  5  1      240.         60.  2       480.         600.  0         0.           0.        1200.
 2  6  1      120.        120.  2       300.         600.  2       300.         300.        3600.
 2  7  1     1800.       1800.  2      3600.        9191.  0      1800.           0.           0.
 2  8  1      300.        360.  2       300.         600.  0        60.           0.           0.
 2  9  1      180.        300.  2       300.         180.  0         0.           0.        1500.
 2 10  1      180.        120.  2       300.         600.  0         0.           0.           0.

NUMBER OF STUDENTS= 20
DEVIDED EQUALLY INTO 2 GROUPS

ALL TIMES ARE IN SECONDS


THE DATA ELEMENT=9191. OR 91 SIGNIFIES THAT NO ACTUAL DATA SU

TOTAL PROGRAMMING TIME (INCLUDES DEBUG TIME)

PROBLEM 1  K-LANGUAGE  F-LANGUAGE
                 150.       2400.
                  90.        300.
                 240.        792.
                 180.       5400.
                 300.      10800.
                 240.       1800.
                3600.         90.
                 660.        450.
                 480.       1800.
                 300.        900.

PROBLEM 2
                  60.        300.
                  90.        630.
                 900.        300.
                  60.        390.
                 120.        480.
                 600.        600.
                  40.       5400.
                  50.        360.
                 264.        300.
                 240.        300.
```

```
MEAN PROGRAMMING TIME (TOTAL) OF EACH PROBLEM-LANGUAGE COMBINATION

          K-LANGUAGE  F-LANGUAGE

PROBLEM 1       624.        2473.

PROBLEM 2       242.         906.

STANDARD DEVIATION (PROG. TIME) OF EACH PROBLEM LANGUAGE COMBINATION

          K-LANGUAGE  F-LANGUAGE

PROBLEM 1      1005.        3140.

PROBLEM 2       273.        1503.

S1=  0.2058821E 09

S2=  0.7385696E 08

S3=  0.6084819E 08

S4=  0.5455734E 08

S5=  0.4506278E 08

S6=TOTAL SUM OF SQUARES=  0.1608193E 09

S7=WITHIN-CELLS OF SQUARES=  0.1320253E 09

S8=ROWS SUMS OF SQUARES=  0.9494560E 07

S9=COLUMNS SUM OF SQUARES=  0.1578541E 08

S10=INTERACTION SUM OF SQUARES=  0.3514112E 07

MSWC=  0.3667368E 07

PROBLEM F(1,4(L-1))=  0.2588930E 01

LANGUAGE F(1,4(L-1))=  0.4304288E 01

4(L-1)=  0.3600000E 02
```

```
SET#2

RAW DATA
COL.1=GROUP NUMBER  COL.2=STUDENT NUMBER WITHIN GROUP
COL.3=K-PROBLEM NUMBER  COL.4=K-PROGRAMMING TIME  COL.5=K-DEBUG TIME
COL.6=F-PROBLEM NUMBER  COL.7=F-PROGRAMMING TIME  COL.8=F-KEYPUNCH TIME
COL.9=NUMBER OF DEBUG RUNS  COL.10=F-DEBUG TIME  COL.11=DEBUG KEYPUNCH TIME
COL.12=WAIT TIME FOR RESULTS

(1)(2)(3)    (4)        (5)   (6)    (7)        (8)   (9)    (10)       (11)       (12)


 1  1  2     380.        0.   1     5100.      1800.  1     1200.        0.      2700.
 1  2  2      50.        0.   1       70.       165.  0        0.        0.      2400.
 1  3  2      60.        0.   1     1200.      1200.  2      600.      300.      1300.
 1  4  2     300.        0.   1      300.       420.  0        0.        0.      1200.
 1  5  2      10.        0.   1      600.       300.  1        0.        0.       900.
 1  6  2      55.        0.   1     1200.       900.  0        0.        0.       900.
 1  7  2     300.        0.   1     2700.      9191.  1     1350.      300.      1300.
 1  8  2     600.        0.   1      960.       300.  0        0.        0.       900.
 1  9  2     300.      180.   1      600.       300.  0        0.        0.      1300.
 1 10  2     900.      180.   1      600.      1200.  2     3600.     1800.      1800.
 1 11  2     200.      180.   1     1200.       600.  2      900.      300.      1800.
 1 12  2     240.      120.   1      600.       600.  2     5400.      180.      7200.
 1 13  2     300.      300.   1     1800.       900.  1      300.      180.       600.
 1 14  2     180.      120.   1      600.       900.  4     2700.     1200.     16200.
 1 15  2    2700.      300.   1     9000.      1200.  3     6300.      900.      5100.
 1 16  2    1800.       35.   1     2700.       900.  2     6300.      900.     18000.
 1 17  2     300.      300.   1     3600.       600.  3     1800.      600.     16200.
 2  1  1     180.        0.   2     2700.      2700.  2     1200.      600.      7200.
 2  2  1      60.        0.   2      600.       900.  0        0.        0.      1500.
 2  3  1      50.        0.   2       90.       300.  1      120.       60.      4500.
 2  4  1     180.       60.   2      420.       300.  0        0.        0.       600.
 2  5  1    1200.      300.   2      600.       600. 91     1200.     9191.      1200.
 2  6  1     900.      600.   2     1200.       600.  1      240.       60.      2100.
 2  7  1     120.       60.   2      180.       600.  2      600.     1200.      5400.
 2  8  1     620.      185.   2      300.       360.  3      120.       60.      1800.
 2  9  1    1500.       60.   2      900.       600.  1      300.        0.      1800.
 2 10  1     120.        5.   2      300.       300.  2     1200.      300.      3600.
 2 11  1     130.      300.   2      180.       600.  1       60.       60.      2700.
 2 12  1     900.      150.   2      600.       420.  0        0.        0.       720.
 2 13  1     300.       30.   2      900.       600.  1      300.      120.      2700.
 2 14  1     315.       50.   2      600.       900.  2      300.       60.       900.
 2 15  1     300.        0.   2      900.      1200.  1       60.      120.       720.
 2 16  1     120.       60.   2      900.       900.  1       60.       30.      1800.
 2 17  1     660.      360.   2      900.      1200.  1      300.      180.      3900.

NUMBER OF STUDENTS= 34
DEVIDED EQUALLY INTO 2 GROUPS

ALL TIMES ARE IN SECONDS
```

```
THE DATA ELEMENT=9191. OR 91 SIGNIFIES THAT NO ACTUAL DATA SUPPLIED

TOTAL PROGRAMMING TIME (INCLUDES DEBUG TIME)

PROBLEM 1  K-LANGUAGE  F-LANGUAGE
                 180.        6300.
                  60.          70.
                  50.        1800.
                 240.         300.
                1560.         600.
                1500.        1200.
                 130.        4050.
                 805.         960.
                1560.         600.
                 125.        4200.
                 430.        2100.
                1050.        6000.
                 330.        2100.
                 365.        3300.
                 300.       15300.
                 180.        9000.
                1020.        5400.

PROBLEM 2
                 380.        3900.
                  50.         600.
                  60.         210.
                 300.         420.
                  10.        1800.
                  55.        1440.
                 300.         780.
                 600.         420.
                 480.        1200.
                1080.        1500.
                 380.         240.
                 360.         600.
                 600.        1200.
                 300.         900.
                3000.         960.
                1835.         960.
                 600.        1200.

MEAN PROGRAMMING TIME (TOTAL) OF EACH PROBLEM-LANGUAGE COMBINATION

           K-LANGUAGE  F-LANGUAGE

PROBLEM 1       581.        3722.

PROBLEM 2       611.        1078.
```

```
STANDARD DEVIATION (PROG. TIME) OF EACH PROBLEM LANGUAGE COMBINATION

          K-LANGUAGE  F-LANGUAGE

PROBLEM 1       525.        3793,

PROBLEM 2       735.         832.

S1=  0.5375962E 09

S2=  0.2674006E 09

S3=  0.2079664E 09

S4=  0.1816614E 09

S5=  0.1526252E 09

S6=TOTAL SUM OF SQUARES=  0.3849707E 09

S7=WITHIN-CELLS OF SQUARES=  0.2701955E 09

S8=ROWS SUMS OF SQUARES=  0.2903624E 08

S9=COLUMNS SUM OF SQUARES=  0.5534125E 08

S10=INTERACTION SUM OF SQUARES=  0.3039792E 08

MSWC=  0.4221804E 07

PROBLEM F(1,4(L-1))=  0.6877635E 01

LANGUAGE F(1,4(L-1))=  0.1310844E 02

4(L-1)=  0.6400000E 02
```

```
SET#2.(WEIGHTED DEBUG TIME, +50% INCORRECT PROGRAM, +20% MINOR ERROR)

RAW DATA
COL.1=GROUP NUMBER  COL.2=STUDENT NUMBER WITHIN GROUP
COL.3=K-PROBLEM NUMBER  COL.4=K-PROGRAMMING TIME  COL.5=K-DEBUG TIME
COL.6=F-PROBLEM NUMBER  COL.7=F-PROGRAMMING TIME  COL.8=F-KEYPUNCH TIME
COL.9=NUMBER OF DEBUG RUNS  COL.10=F-DEBUG TIME  COL.11=DEBUG KEYPUNCH TIME
COL.12=WAIT TIME FOR RESULTS

(1)(2)(3)     (4)        (5)   (6)    (7)        (8)   (9)    (10)      (11)      (12)

 1  1  2     380.         0.  1     5100.     1800.  1     1200.        0.      2700.
 1  2  2      50.         0.  1       70.      165.  0        0.        0.      2400.
 1  3  2      60.         0.  1     1200.     1200.  2      600.      300.      1800.
 1  4  2     300.         0.  1      300.      420.  0        0.        0.      1200.
 1  5  2      10.         0.  1      600.      300.  1        0.        0.       900.
 1  6  2      55.         0.  1     1200.      900.  0      600.        0.       900.
 1  7  2     300.         0.  1     2700.     9191.  1     1350.      300.      1800.
 1  8  2     600.         0.  1      960.      300.  0        0.        0.       900.
 1  9  2     300.       180.  1      600.      300.  0        0.        0.      1800.
 1 10  2     900.       180.  1      600.     1200.  2     3900.     1800.      1900.
 1 11  2     200.       180.  1     1200.      600.  2     1500.      300.      1800.
 1 12  2     240.       120.  1      600.      600.  2     5400.      180.      7200.
 1 13  2     300.       300.  1     1800.      900.  1     1200.      180.       600.
 1 14  2     180.       120.  1      600.      900.  4     3000.     1200.     16200.
 1 15  2    2700.       300.  1     9000.     1200.  3    10800.      900.      5100.
 1 16  2    1800.        35.  1     2700.      900.  2     6300.      900.     18000.
 1 17  2     300.       300.  1     3600.      600.  3     1800.      600.     16200.
 2  1  1     180.         0.  2     2700.     2700.  2     1200.      600.      7200.
 2  2  1      60.         0.  2      600.      900.  0        0.        0.      1500.
 2  3  1      50.         0.  2       90.      300.  1      120.       60.      4500.
 2  4  1     180.        60.  2      420.      300.  0        0.        0.       600.
 2  5  1    1200.       300.  2      600.      600. 91     1200.     9191.      1200.
 2  6  1     900.       600.  2     1200.      600.  1      240.       60.      2100.
 2  7  1     120.        60.  2      180.      600.  2      600.     1200.      5400.
 2  8  1     620.       185.  2      300.      360.  3      120.       60.      1800.
 2  9  1    1500.        60.  2      900.      600.  1      300.        0.      1800.
 2 10  1     120.         5.  2      300.      300.  2     1200.      300.      3600.
 2 11  1     130.       300.  2      180.      600.  1       60.       60.      2700.
 2 12  1     900.       150.  2      600.      420.  0        0.        0.       720.
 2 13  1     300.        30.  2      900.      600.  1      300.      120.      2700.
 2 14  1     315.        50.  2      600.      900.  2      300.       60.       900.
 2 15  1     300.         0.  2      900.     1200.  1       60.      120.       720.
 2 16  1     120.        60.  2      900.      900.  1       60.       30.      1800.
 2 17  1     660.       360.  2      900.     1200.  1      300.      180.      3900.

NUMBER OF STUDENTS= 34
DEVIDED EQUALLY INTO 2 GROUPS

ALL TIMES ARE IN SECONDS


THE DATA ELEMENT=9191. OR 91 SIGNIFIES THAT NO ACTUAL DATA SUPPLIED
```

```
TOTAL PROGRAMMING TIME (INCLUDES DEBUG TIME)

PROBLEM 1  K-LANGUAGE  F-LANGUAGE
                 180.       6300.
                  60.         70.
                  50.       1300.
                 240.        300.
                1500.        600.
                1500.       1300.
                 180.       4050.
                 805.        960.
                1560.        600.
                 125.       4500.
                 430.       2700.
                1050.       6000.
                 330.       3000.
                 365.       3600.
                 300.      19800.
                 180.       9000.
                1020.       5400.

PROBLEM 2
                 380.       3900.
                  50.        600.
                  60.        210.
                 300.        420.
                  10.       1800.
                  55.       1440.
                 300.        780.
                 600.        420.
                 480.       1200.
                1080.       1500.
                 380.        240.
                 360.        600.
                 600.       1200.
                 300.        900.
                3000.        960.
                1835.        960.
                 600.       1200.

MEAN PROGRAMMING TIME (TOTAL) OF EACH PROBLEM-LANGUAGE COMBINATION

           K-LANGUAGE  F-LANGUAGE

PROBLEM 1       581.        4146.

PROBLEM 2       611.        1078.
```

```
STANDARD DEVIATION (PROG. TIME) OF EACH PROBLEM LANGUAGE COMBINATION

           K-LANGUAGE  F-LANGUAGE

PROBLEM 1        525.        4601.

PROBLEM 2        735.         832.

S1=  0.7094961E 09

S2=  0.3240517E 09

S3=  0.2440553E 09

S4=  0.2141693E 09

S5=  0.1749611E 09

S6=TOTAL SUM OF SQUARES=  0.5345349E 09

S7=WITHIN-CELLS OF SQUARES=  0.3854443E 09

S8=ROWS SUMS OF SQUARES=  0.3920829E 08

S9=COLUMNS SUM OF SQUARES=  0.6909427E 08

S10=INTERACTION SUM OF SQUARES=  0.4078810E 08

MSWC=  0.6022568E 07

PROBLEM F(1,4(L-1))=  0.6510227E 01

LANGUAGE F(1,4(L-1))=  0.1147256E 02

4(L-1)=  0.6400000E 02
```

APPENDIX C

REFERENCE MANUAL

APPENDIX C

The following two pages are the two sides of the K-M reference map given to students during the initial lecture

REFERENCE MANUAL

Vocabulary List

ABS
ABSOLUTE
AND
ARC
ARCCOS
ARCCOSH
ARCCOT
ARCCOTH
ARCCSC
ARCCSCH
ARCSEC
ARCSECH
ARCSIN
ARCSINH
ARCTAN
ARCTANH
BY
CALL

CARD
CARDS
COMPUTE
CONTINUE
COS
COSECANT
COSH
COSINE
COT
COTANGENT
COTH
CSC
CSCH
CYCLE
DIMENSION
DIVIDED
DO
ELSE

END
EOF
EQUALS
EXP
FILE
FINISH
FOR
FORMAT
FORMULA
FRACTIONAL
FROM
GO
HEADING
IF
INFINITY
LABEL
LINE
LINES

LN
LOG
LOOP
MAXIMUM
MESSAGE
MINUS
OF
OR
OTHERWISE
PART
PAUSE
PERFORM
PLOT
PLUS
PRINT
PROCEDURE
PROGRAM
PUNCH

READ
RETURN
REWIND
ROUND
SEC
SECANT
SECH
SIN
SINE
SINH
SLEW
SPECIAL
SQRT
STATEMENT
STOP
SUBROUTINE
SWITCH
TAN

TANGENT
TANH
TAPE
THE
THEN
TIMES
TO
TOP
TRUNCATE
TYPE
UNTIL
UPPER
VARIABLE
VARIABLES
WITHIN
WRITE

A period denotes the end of a statement or the end of an implied loop.

Corrections can be made by overtyping or by pressing the control key ERASE when positioned over the error.

Each program must be terminated by the statement END OF PROGRAM or FINISH.

More than one statement per typing line is acceptable.

To continue a statement beyond the *maximum typing length* for one line, press the carriage return as many times as desired.

Names of variables with more than one character should be defined by a SPECIAL VARIABLES statement before use.

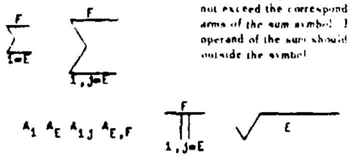
A comma or the word AND may be used to separate computable statements.

```
FROM   1 TO 10 COMPUTE A,  B, C..., C,  A...X AND D  SIN θ.
```

Superscripts and subscripts must be in straight line form but forms such as (A^{E})^{F} are permissible.

Examples of Acceptable Forms

The letters E, F, G denote an arithmetic expression, e.g. F may denote the expression A + 2B + c, otherwise a single variable is meant. Braces { } denote a choice of forms. Square Brackets [ ] denote those forms that are optional.



Note: The horizontal extension of the lower limit equation and upper limit expression should not exceed the corresponding arms of the sum symbol. The operand of the sum should be outside the symbol.

```
DIMENSION A  (N,M).
```

This indicates that A is an (N + 1) by (M + 1) array.

```
DIMENSION B  40, Z  30, Q  (10, 50).
```

SPECIAL VARIABLE[S] DIMENSION

```
SPECIAL VARIABLES TEMPERATURE, HUMIDITY  PRESSURE,
COUNT, LBJ (14  200), ω  10.
```

UPPER is used in the same manner as DIMENSION and SPECIAL VARIABLES except that the indicated arrays are stored in upper memory.

```
UPPER C, WEIGHT  56, K  (20  30).
```

Subscripted variables need not be dimensioned when used in forms such as

```
(1) A_ik  B Q_ik FOR k  0(2)20 AND i  1 TO 5
(2) MAXIMUM n  10, J  15
    A_ik  B,Q_ik FOR k  4,5        J  WITHIN  0 BY 3
    UNTIL n.
```

(3) $A=\sum_{i=1}^{40} B_i, \quad P=\prod_{i,j=0}^{30} C_{ij}$

```
(4) READ TAPE C, 2, 2, 10.
```

```
FROM   E[BY F] {TO / UNTIL} {[k ...]} G

FROM   E TO G  Unit steps assumed
FROM   N BY 2.34 UNTIL A  B
FROM A  B  5 BY 2 UNTIL G  20
FROM   E TO INFINITY

FOR   1, 2, . . . , 5
FOR   5(10)55
FOR   0, 5         7.5
```

Note: Any number of data permissible but no extra spaces before terminating comma. The difference between the first two indices gives the increment in the first FOR form.

FROM or FOR forms can be used either to begin or end a statement.

```
C  A  B  FROM   1 TO 10.
FROM   1 TO 10 COMPUTE A,  B.
```

```
DO [TO / UNTIL]  LOOP [ ]  CYCLE [ ]
DO STATEMENT 5 FROM J  1 TO 10.
```

This indicates that all statements up to but not including 5 will be executed. (No two LOOP statements should terminate at the same statement number. Otherwise, any number of LOOP procedures within or external to other LOOP procedures is permitted.

```
FROM  WITHIN  AND
FOR ω  0, 5, . . . , 90 WITHIN r  1 TO 10 AND n  1 TO 5 LOOP TO
FORMULA 6.
```

The loop to be performed most often is the first one; the least often is the last.

```
READ  READ CARD  READ CARDS
READ A, FROM   1 TO A,  15.
```

Card Format is free field, number of data points may vary from card to card and may be in either fixed or floating point form.

```
READ X.
READ A_i, B_i, FROM   E UNTIL A   93.643.
```

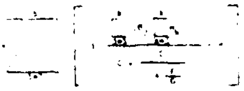
Data may be punched into cards in the following forms

```
2  -2  1.596  +3.211  -4.60  2.7812  2.78+10^3
2.78E-3  2.78×10^-3  2.78E-0  2.78×10^3
```

Each datum should be separated by at least one blank space and the value should be within ±10^[illegible] and not exceed nine significant digits.

Example

```
[illegible] D=35  [illegible]  [illegible]  Q=2  [illegible]
FROM n=1 UNTIL [illegible] COMPUTE B_r=5-n.
PERFORM [illegible] FOR n=1 UNTIL n=5
```



```
PRINT [illegible]
FINISH.
```

Three Alternate Formulations Of The Same Problem

```
MAXIMUM n=20.
READ [illegible]
[illegible]
[illegible]
```

```
DIMENSION [illegible], [illegible].
[illegible], READ [illegible].
FORMULA 1.  READ [illegible]
[illegible]  IF [illegible] GO TO FORMULA 2
[illegible]  STATEMENT 3. [illegible]
STATEMENT 2. [illegible]
[illegible] THEN GO TO STATEMENT 2
[illegible] AND [illegible]
[illegible] GO TO STATEMENT [illegible]
[illegible]
```

```
MAXIMUM [illegible].
READ [illegible]
FROM [illegible] TO [illegible] READ [illegible]
DO FORMULA 3 FROM [illegible] TO [illegible]
[illegible]
FROM [illegible] COMPUTE [illegible]
[illegible]
FORMULA [illegible]  PRINT [illegible]
END OF PROGRAM
```

```
PRINT X   (A, Y, (A,B), Z, SIN(θ - Y), FOR   1, 2   N
PRINT E F (A,B), X G(A).
PUNCH E F (A,B), X G(A).
```

A and B are integers between 0 and 9 but their sum may not exceed 9. F and X will be printed (or card punched) with A places to the left of the decimal point and B places to the right. The value of G and [illegible] will be printed (or card punched) as an integer of A places. G will be stored in A. E, and Z, will be printed (or card punched) in floating point form.

```
PRINT Y E (A,B,C).
```

Same as above except that E is first divided by 10 to change its range.

In the print statement a maximum of 8 expressions (including a blank between commas) are allowed. Each is centered in a 15 position field.

```
PRINT LABEL A, COUNT, X-Y, SIGMA (J).
PRINT LABEL  LABEL  HEADING  PRINT HEADING
```

Each label separated by commas, in a PRINT LABEL statement may be [illegible] characters in length and will be printed in a 15 position field. A maximum of 8 labels per statement is permitted and should contain [illegible] used on the high speed printer.

The PRINT FORMAT statement may be used when it is desired to [illegible] literals and answers or [illegible] more than 8 answers per line.

```
PRINT FORMAT n E F, X G.
FORMAT n LLL  xxxx LLL  L x.xx y.
```

n is an integer of up to four places. LLL stands for any literals that are printable on the high speed printer. Small x's are used to denote the actual position and number of digits of fixed point quantities while one small x is used for each floating point quantity. The first set of x's denotes the first expression, equation, variable mentioned in the PRINT FORMAT statement, the second set of x's denotes the second expression, etc. FORMAT statements may be located anywhere in a program.

```
PRINT FORMAT 12, θ, SIN θ, 180θ/π FROM   1 TO N.
FORMAT 12 ANGLE (RADIANS)  y SIN THETA  x.xxxx AND THE
ANGLE IS xxx DEGREES.
```

If θ, 3π/4 then the following would be printed on the high speed printer

```
"ANGLE (RADIANS) .2356194  SIN THETA .7071 AND THE
ANGLE IS 135 DEGREES."
```

SLEW N (*Printer paper spaced N lines*)
SLEW [[TO]TOP] (*Paper will advance to top of page*)

Messages on the typewriter or printer are printed using the following forms

```
TYPE NEGATIVE SQUARE ROOT.
PRINT MESSAGE (END OF PROGRAM) AND SLEW.

IF F  G THEN GO TO STATEMENT 1.
IF F  G GO TO STATEMENT 1.
IF F  G THEN B - C - E.
IF F  G THEN READ . . . .
IF F  G THEN CONTINUE.
IF F  G THEN . . . [ ELSE      ] [ E       ]
                   [ OTHERWISE ] [ GO TO   ]
                                 [ COMPUTE ]
```

Examples of multiple conditions

```
IF r  S OR G  H OR SIN θ, -β² THEN  { COMPUTE . . .       } OTHER-
                                    { READ α              } WISE
                                    { C - D               }
                                    { GO TO FORMULA 3     }
                                    { CONTINUE            }
IF P  G AND H  , 2 AND . . .
IF U  O OR (G - r SIN θ AND H  Cα) . . .
IF E  F - G THEN . . .

1) COMPUTE A  B - 2, (IF i  j THEN (IF m  n THEN T  r SIN θ)
OTHERWISE  T  r COS θ) and PRINT T, A.
2) COMPUTE A  B - 2, (IF i  j THEN (IF m  n THEN T  r SIN θ
OTHERWISE  T  r COS θ) and PRINT T, A.
```

In case 1 T = r sin θ if i = j and m ≠ n
T = r cos θ when i ≠ j
T is not computed when i = j and m = n.
In case 2 T = r sin θ when i = j and m ≠ n
T = r cos θ when i = j and m = n
T is not computed when i ≠ j.

```
GO , GO[TO]
GO TO STATEMENT 20
```

PAUSE will cause the object program to go into a loop. Exit out of the loop will occur if console switch No. 0 is toggled.

Comments (non-computable statements) are entered between [ ] symbols.

```
FROM i  1 TO 10 READ X, [READ VALUES].
Y(i,j)  i - 12 j.
```

Use of the next forms eliminates the necessity of using "DO" or "LOOP" statements. Computable substatements within an implied loop are separated by a comma or AND.

```
FOR i  1(1)50 AND k  0 BY 2 UNTIL Y  2000 READ X_i,k,
COMPUTE Y  2X_i,k AND PRINT Y.

FROM i  1 TO INFINITY READ X_i, IF X_i  10 COMPUTE Y  [illegible]
n  n - 2 OTHERWISE GO TO STATEMENT 1.
```

Superscripts that are *red* are used to form new characters rather than being interpreted as exponents. The following is a short program to determine the maximum absolute value of a set of [illegible]

```
FROM i  1 TO 100 IF  X_i  X^MAX THEN X^MAX  X_i [illegible]
```

In the following magnetic tape commands L is the number of elements in the array V, T is the tape number and P is the controller plug [illegible]

```
READ TAPE V_i, T, P, L. The first L [illegible] of the tape record is
   read into locations V_i [illegible]
WRITE TAPE V_i, T, P, S. Locations [illegible] V_6 are written on tape
REWIND T, P.  RWD T, P
WRITE END OF FILE T, P.   EOF T, P.
IF END OF FILE P THEN . . .    IF EOF P GO TO . . .
```

In the following example Y is the variable to be plotted, X is the "independent index" (i.e. Y = f(X)), A the minimum value of Y and B the maximum value of Y.

```
PLOT Y, X, A, B.  PLOT Z_i, i, 0, 1 FROM i  1 TO 565.
```

EXAMPLES

```
READ A_i, COMPUTE Y= A_i/[illegible] AND PLOT Y, I, -1, 1 FROM I=1
UNTIL Y>1.

IF a>k COMPUTE x=[illegible] (a-k [illegible], Y=[illegible] AND PRINT Y,
a, T, k, OTHERWISE COMPUTE x=2ak, Y=B_ij[illegible] AND PRINT Y,
a, T, k FROM a=1 TO r WITHIN 1e2 BY [illegible] AND FOR
k=0(5)90.

FROM i=1 TO 10 AND j=1 TO 10 READ A_ij,
COMPUTE B_ij=A_ij*X_i+Y_j AND PRINT A_ij, B_ij, [illegible]

FOR n=1, 2, ..., 10 AND FOR [illegible] COMPUTE [illegible],
C_p= [illegible] , [illegible] TAN [illegible] ,
V_p= [illegible] AND PRINT r, θ, V_p, A

IF (A>Y AND Y>C) OR ( [illegible] x+Y)² THEN COMPUTE
T_xy=[illegible])² AND W=(YT_xy)^[illegible] AND PRINT W, T_xy, [illegible] FROM
y=2k+3 BY .01Y UNTIL W>5000 AND FROM x=1 TO 100
OTHERWISE GO TO STATEMENT 2.
```

To define a procedure within a program

```
(SUBROUTINE)
(PROCEDURE )  Name [illegible]

. . . . . . . . . . . . . RETURN . . .

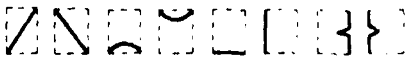
RETURN      [END [(Name)] [ SUBROUTINE ] ]
                          [ PROCEDURE  ]
```

The name of a subroutine can be an alphanumeric string of any length but must begin with an alphabetic character and cannot be identical to any item in the vocabulary list. As many RETURN's as desired may be inserted to branch out of the subroutine back to the main program. The END statement is optional. A STOP or GO TO st[illegible] routines.

To call a procedure

```
CALL (Name) [ SUBROUTINE ]
            [ PROCEDURE  ]
```

Relative Positions of Special Characters



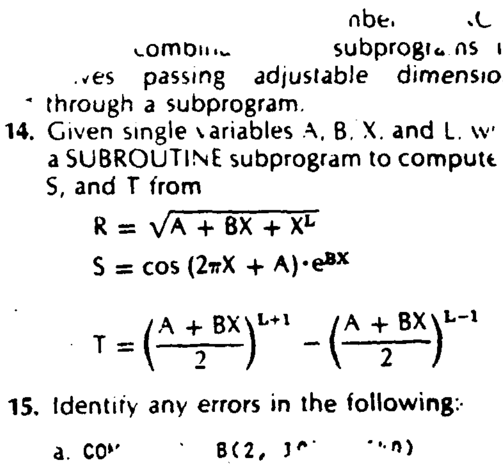
Necessary Reference Citation
[illegible] KEEBER and [illegible] REFERENCE [illegible]
Columbia University, Hudson Laboratories
Dobbs Ferry, New York
Revised Edition July [illegible]
This work has been supported by the Office of Naval Research under [illegible] the Office of Research Projects [illegible]

APPENDIX D

McCracken Problems

vs.

Corresponding K-M Programs



nbe. .C
combi... subprogra ns ii.
.ves passing adjustable dimension
through a subprogram.

14. Given single variables A, B, X, and L, w a SUBROUTINE subprogram to compute S, and T from

$$R = \sqrt{A + BX + X^L}$$

$$S = \cos(2\pi X + A)\cdot e^{BX}$$

$$T = \left(\frac{A + BX}{2}\right)^{L+1} - \left(\frac{A + BX}{2}\right)^{L-1}$$

15. Identify any errors in the following:

a. CO B(2, 1

{PROBLEM 14, PAGE 195}

SUBROUTINE RST.

$$R = \sqrt{A+BX+X^L} ,$$

$$S = COS(2\pi X+A)e^{BX} , \text{ AND}$$

$$T = \left\{\frac{A+BX}{2}\right\}^{L+1} - \left\{\frac{A+BX}{2}\right\}^{L-1} .$$

RETURN.

$$\overline{- 4ac}$$

$$\cdot X2 = \frac{-\qquad \sqrt{b^2 - 4ac}}{2a}$$

WRITE: *a*, *b*, *c*, *X*1, *X*2

✓ **5.** READ: *a*, *b*, *c*, *x*
Evaluate:

$$r = \frac{b \cdot c}{12}\left[6x^2\left(1 - \frac{x}{a}\right) + b^2\left(1 - \frac{x}{a}\right)^3\right]$$

WRITE: *a*, *b*, *c*, *x*, *r*

***6.** READ: *a*, *e*, *h*, *p*
Evaluate:

$$x = \qquad \frac{\cdot\ h \cdot P}{\cdot}$$

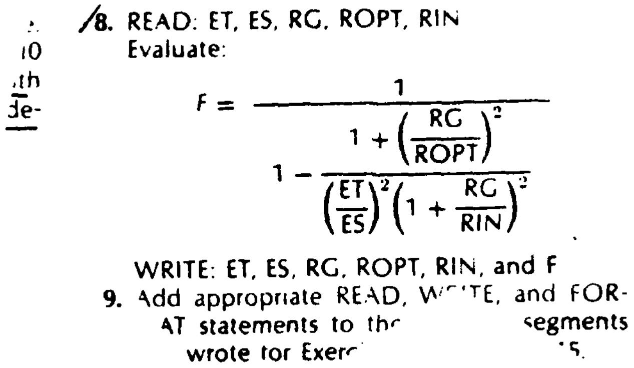
(sc
actu
grai
sol
act
unce
runni
is encc
to w'
stre
to

PROBLEM 5, PAGE 19

```
READ A,B,C,X.
```

$$R= \frac{BC}{12}\left[6X^2 \left\{ 1- \frac{X}{A} \right\} + B^2 \left\{ 1- \frac{X}{A} \right\}^3 \right].$$

```
PRINT A,B,C,X,R.  FINISH.
```



: 10 th de-

/8. READ: ET, ES, RG, ROPT, RIN
Evaluate:

$$F = \frac{1}{1 - \dfrac{1 + \left(\dfrac{RG}{ROPT}\right)^2}{\left(\dfrac{ET}{ES}\right)^2\left(1 + \dfrac{RG}{RIN}\right)^2}}$$

WRITE: ET, ES, RG, ROPT, RIN, and F

9. Add appropriate READ, W‾'TE, and FOR-
AT statements to th‾ segments
wrote for Exer‾ 'S.

{PROBLEM 8, PAGE 19}

SPECIAL VARIABLES ET,ES,RG,ROPT,RIN.
READ ET,ES,RG,ROPT,RIN.

$$F= \frac{1}{1- \dfrac{1+(\frac{RG}{ROPT})^2}{(\frac{ET}{ES})^2\ (1+\frac{RG}{RIN})^2}}$$

PRINT ET,ES,RG,ROPT,RIN,F. FINISH.

,J) · .id
row, . usi.

(c) Replac. ..ch elem ..ird row by the sum of the c.. ..nding elements from the first an.. second rows, using a loop.

4. A two-dimensional array named XYZ3 contains four rows and three columns. Write separate program segments to accomplish the following:

(a) Replace all the elements in the fourth row by zeros.

(b) If the product of the first element in the first row, the second element in the second row, and the third element in the third row is less than 10^{-5} in absolute value, place a zero in DET.

(c) Replace each element in the second column by the average of the corresponding elements in the first and third columns.

*5. A three-dimensional array named PUPILS contains information about the pupil population of a cer.. .n school district, organized as fol.. ..irst subscript distin- ..hes .. .. girls: 1 for ..

{PROBLEM 4, PAGE 89}

```
DIMENSION XYZ3=(4,3),DET=1.

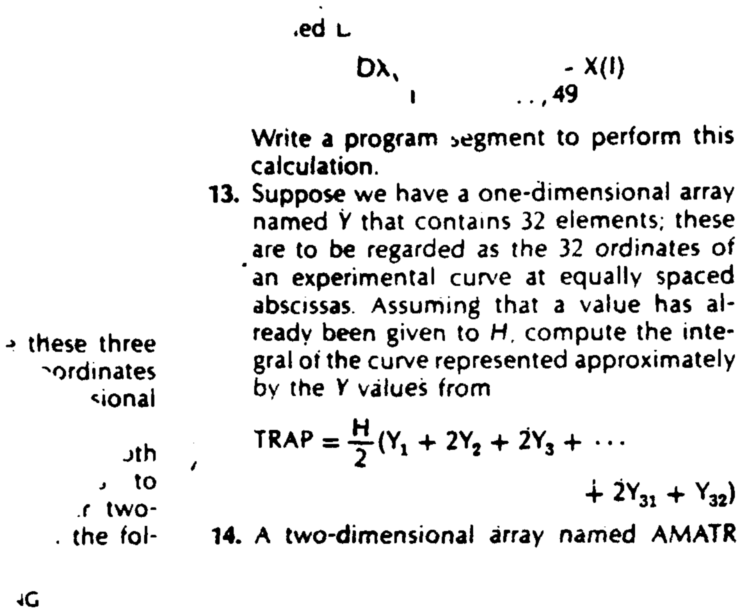
FROM j=1 TO 3  $XYZ3_{4,j} = 0$ .

IF $|(XYZ3_{1,1})\ (XYZ3_{2,2})\ (XYZ3_{3,3})| < 10^{-5}$

THEN DET=0 .

FROM i=1 TO 4  $XYZ3_{i,2} = \frac{XYZ3_{i,1} + XYZ3_{i,3}}{2}$ .

FINISH.
```



.ed L

DX, - X(I)

I . . , 49

Write a program segment to perform this calculation.

13. Suppose we have a one-dimensional array named Y that contains 32 elements; these are to be regarded as the 32 ordinates of an experimental curve at equally spaced abscissas. Assuming that a value has already been given to *H*, compute the integral of the curve represented approximately by the *Y* values from

$$\text{TRAP} = \frac{H}{2}(Y_1 + 2Y_2 + 2Y_3 + \cdots + 2Y_{31} + Y_{32})$$

14. A two-dimensional array named AMATR

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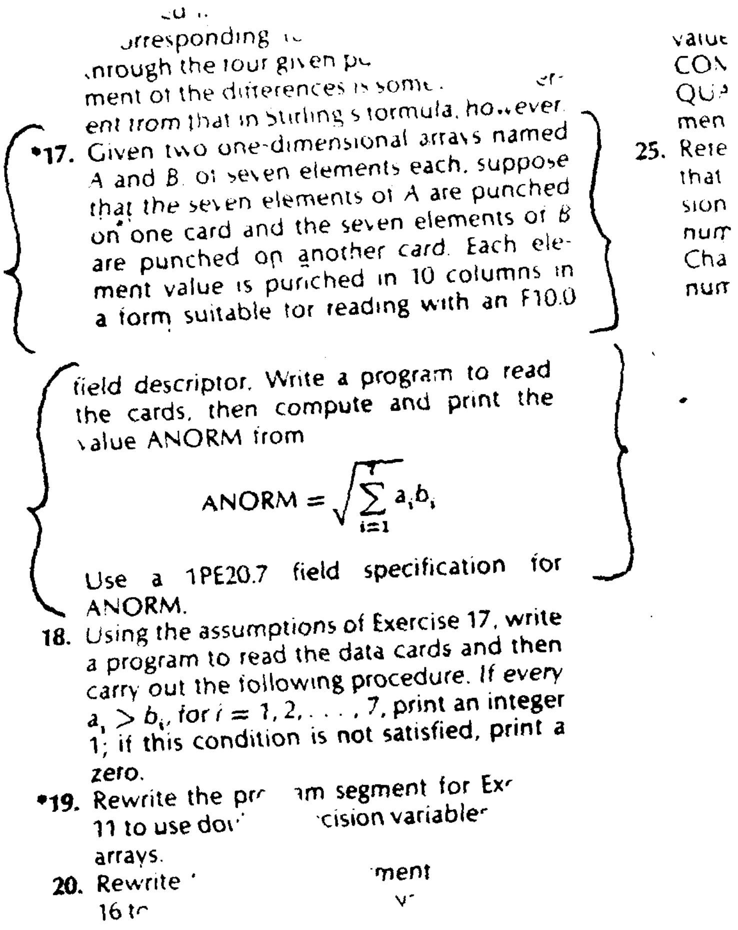
G

{PROBLEM 13, PAGE 90}

SPECIAL VARIABLE TRAP.

$$\text{TRAP}= \frac{H}{2} \left(Y_1+2 \sum_{1=2}^{31} Y_1 + Y_{32} \right) . \text{ FINISH.}$$



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through the four given p[illegible]
ment of the differences is some[illegible] er-
ent from that in Stirling's formula, however

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*17. Given two one-dimensional arrays named A and B, of seven elements each, suppose that the seven elements of A are punched on one card and the seven elements of B are punched on another card. Each element value is punched in 10 columns in a form suitable for reading with an F10.0 field descriptor. Write a program to read the cards, then compute and print the value ANORM from

$$\text{ANORM} = \sqrt{\sum_{i=1}^{7} a_i b_i}$$

Use a 1PE20.7 field specification for ANORM.

18. Using the assumptions of Exercise 17, write a program to read the data cards and then carry out the following procedure. If every $a_i > b_i$, for $i = 1, 2, \ldots, 7$, print an integer 1; if this condition is not satisfied, print a zero.

*19. Rewrite the pr[illegible] am segment for Ex[illegible] 11 to use do[illegible] [illegible]cision variable[illegible] arrays.

20. Rewrite [illegible] [illegible]ment 16 t[illegible] v[illegible]

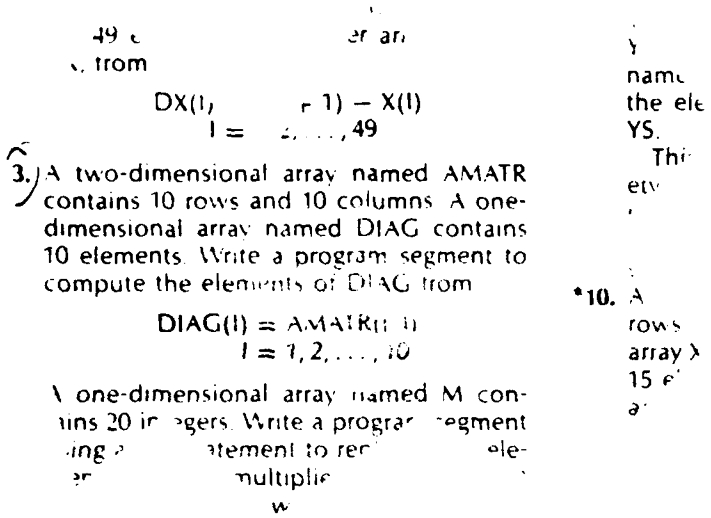
```
PROBLEM 18, PAGE 91 (ALT. INTERP.)

READ A_i FROM i=1 TO 7.

READ B_i FROM i=1 TO 7.

X=1.  FROM i=1 TO 7 IF A_i≤B_i THEN

X=0.  PRINT X{1}.  FINISH.
```



49 e er ar
, from

DX(I, r 1) − X(I)
I = , . . . , 49

3. A two-dimensional array named AMATR contains 10 rows and 10 columns. A one-dimensional array named DIAG contains 10 elements. Write a program segment to compute the elements of DIAG from

DIAG(I) = AMATR(I, I)
I = 1, 2, . . . , 10

\ one-dimensional array named M contains 20 in egers. Write a progra egment ing a atement to rer ele- er multiplie w

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*10. A
rows
array X
15 e
a

PROBLEM 3, PAGE 115

```
DIMENSION AMATR=(10,10), DIAG=10.

FOR I=1,2,...,10  DIAG(I)=AMATR(I,I).

FINISH.
```

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program
compute
named

ATR
one-
tains
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ents in BIGB and ... ıent numb
BIGB in NBIGB.

9. *Two one-dimensional arrays named* X *and* Y contain 50 elements each. A variable named XS is known to be equal to one of the elements in X. If XS = X_i, place Y_i in YS.

This kind of *table search* has a wide variety of applications, such as finding a value in a table of electric utility rates from a rate code or finding the numerical code corresponding to an alphabetic name.

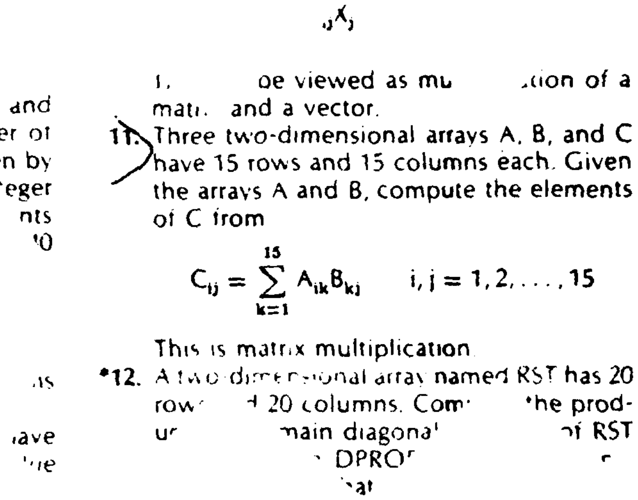
***10.** A tw ımensional array A tains 15
ro columns. A or onal
15 elemer he
ne-d

PROBLEM 9, PAGE 115

DIMENSION X=50, Y=50, XS=1, YS=1.

FROM 1=1 TO 50 IF XS=X_1 THEN YS=Y_1 .

FINISH.



$_{ij}X_j$

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ı, oe viewed as mu .tion of a matı. and a vector.

11. Three two-dimensional arrays A, B, and C have 15 rows and 15 columns each. Given the arrays A and B, compute the elements of C from

$$C_{ij} = \sum_{k=1}^{15} A_{ik}B_{kj} \qquad i, j = 1, 2, \ldots, 15$$

This is matrix multiplication.

.ıs
ıave
'ne

*12. A two-dimensional array named RST has 20 row d 20 columns. Com 'he product main diagona' of RST DPRO 'at

{PROBLEM 11, PAGE 115}

DIMENSION A=(15,15), B=(15,15), C=(15,15).

$$C_{i,j} = \sum_{k=1}^{15} A_{ik}B_{kj} \quad \text{FOR } i=1,2,\ldots,15$$

AND j=1,2,...,15. FINISH.

$\overline{Y^4 + \backslash}$

$\backslash =$

$\overline{\sin^2 Y + \sqrt{1 + \ldots}} \quad . \quad \overline{\overline{+ 3 \sin^2 Y}}$

Define a statement function to compute

$$SLG(A) = 2.549 \log\left(A + A^2 + \frac{1}{A}\right)$$

Then use the function to compute

$$R = X + \log X + 2.549 \log\left(A + A^2 + \frac{1}{A}\right)$$

$$S = \cos X + 2.549 \log \left(1 + X + (1 + X)^2 + \frac{1}{1 + X}\right)$$

$$T = 2.549 \log \left[(A - B)^3 + (A - B)^6 + \frac{1}{(A - B)^3}\right]$$

$$U = [B(I) + 6]^2 + 2.549 \log\left[\frac{1}{B(I)} + \frac{1}{B(I)^2} + B(I)\right]$$

*3. Define a logical statement ~ction to cor ~ute the "exclusive or" ~ical v~ ~. The exclusiv~ ~ of the ir ~ ~nut~

7. W~ pu~

of ~ A; c~

8. Re~

Problem 2, page 194

FUNCTION $SLG(A)=2.549\ LOG(A+A^2+\frac{1}{A})$

$R=X+LOG(X)+SLG(A).$

$S=COS(X)+SLG(1+X).$

$T=SLG\ [\ (A-B)^3\ ]\ .$

$U=[\ B_I\ +\ 6\ ]^2\ +\ SLG(\frac{1}{B_I})\ .$

FINISH.

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ners on th .nate axes.

2. In the following exercises you are to draw a flowchart and write a complete program, including input and output. You may use F10.0 field specifications for all input and 1PE15.6 for all output.

*(a) Read the value of ANNERN; print ANNERN and compute and print TAX according to the following table:

ANNERN (annual earnings)	TAX
Less than $2000	Zero
$2000 or more but less than $5000	2% of the amount over $2000
$5000 or more	$60 plus 5% of the amount over $5000

(b) GROSS is an employee's earnings for the year; DEPEND is the number of dependents he claims. Multiply DEPEND by 675.00, subtract the product from GROSS, and place the difference in TAXABL. However, if this difference is negative, place zero in TAXABL.

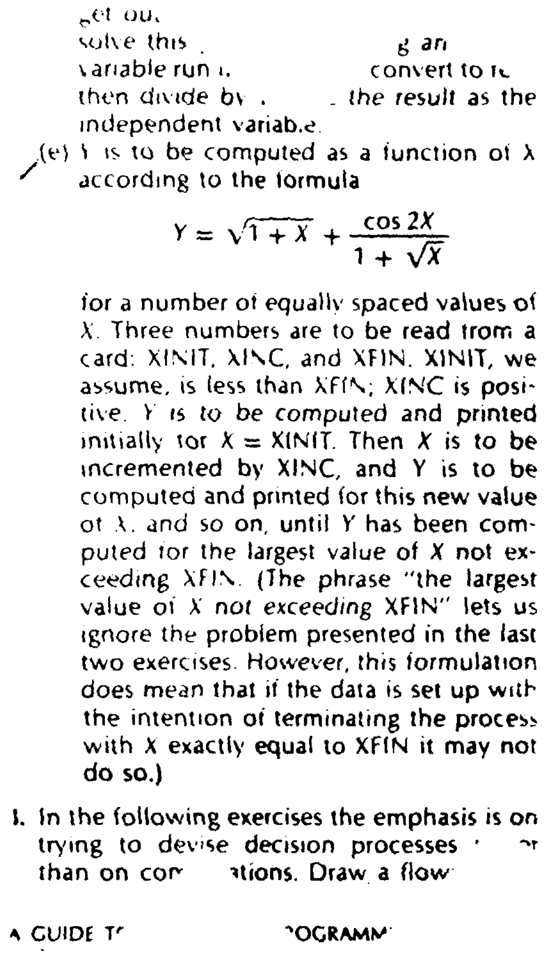
```
<PROBLEM 2B, PAGE 49>

SPECIAL VARIABLES GROSS, DEPEND, TAXABLE.

TAXABLE=GROSS-(675)DEPEND.

IF TAXABLE<0 THEN TAXABLE=0.

FINISH.
```



get ou
solve this g an
variable run i convert to t
then divide by . the result as the
independent variable.

(e) Y is to be computed as a function of X according to the formula

$$Y = \sqrt{1 + X} + \frac{\cos 2X}{1 + \sqrt{X}}$$

for a number of equally spaced values of X. Three numbers are to be read from a card: XINIT, XINC, and XFIN. XINIT, we assume, is less than XFIN; XINC is positive. Y is to be computed and printed initially for X = XINIT. Then X is to be incremented by XINC, and Y is to be computed and printed for this new value of X, and so on, until Y has been computed for the largest value of X not exceeding XFIN. (The phrase "the largest value of X *not exceeding* XFIN" lets us ignore the problem presented in the last two exercises. However, this formulation does mean that if the data is set up with the intention of terminating the process with X exactly equal to XFIN it may not do so.)

3. In the following exercises the emphasis is on trying to devise decision processes r than on com ations. Draw a flow

A GUIDE T OGRAMM

```
{PROBLEM 2E, PAGE 50}

SPECIAL VARIABLES XINIT, XINC, XFIN .

READ XINIT, XINC, XFIN.

FROM X=XINIT BY XINC UNTIL X>XFIN

PRINT Y= $\sqrt{1+X} + \frac{\cos(2X)}{1+\sqrt{X}}$ ,

FINISH.
```

APPENDIX E

K-M Examples

(Programs as Compiled and Executed)

APPENDIX E

The following 20 pages are the K-M example set give to students during the initial lecture.

KM examples

$$\theta_{\alpha\beta} = \int_{2}^{n} \int_{3}^{\sqrt{\frac{y}{n}}} \frac{\frac{e^{-\alpha x}}{y+n} \sum_{1,j=1}^{n} \left[\text{COS } y + \frac{\text{SIN}^{1+j} x}{(1+j)x} \right]}{\frac{\text{LOG}_2\, x + \text{TAN}^{-1} \frac{x^n}{y^{n-1}}}{\sqrt{\frac{\alpha}{\beta + \frac{\gamma}{y}} + \frac{\alpha + \frac{\gamma}{\beta}}{x}}} + \prod_{k=1}^{n^2-\alpha^2} \left[\frac{\beta^{k+1}}{k} + (x+ky)^{-k} \right]} \, dx\, dy \, .$$

To make this an executable program, you need only type additional statements to read in or compute, or assign values for n, β, α, etc. An answer will be printed out only if the integral converges for the parameters input. Else the appropriate message of non-convergence will be output.

```
           2
*→   FROM I=2 BY 2.5 UNTIL I> 60  PRINT I(2.2) .

     FINISH.

90010  FROM I=2 BY 2.5 UNTIL I GREATER THAN OR EQUAL:TO 60 PRINT;I(2,
2)
90020 FINISH  ↖
               *

        X14=3.14159265
        X15=2.7182818
97777   FORMAT (E14.8)
        X57=2.
        Q1=(Q=2.5)/ABSF(Q)
        GOTO 90001
90002   X57=X57+2.5
90001   IF((X57-(60.)))90004,90003,90003
90004   P1=X57
90005   FORMAT (F10.2,4X)
        WRITE 2,90005,P1
        GOTO 90002
90003   CONTINUE
        END
```

* Note: error in typing corrected by back spacing and overtyping with correct character

```
    2.00
    4.50
    7.00
    9.50
   12.00
   14.50
   17.00
   19.50
   22.00
   24.50
   27.00
   29.50
   32.00
   34.50
   37.00
   39.50
   42.00
   44.50
   47.00
   49.50
   52.00
   54.50
   57.00
   59.50  ←
```

note termination point

MAXIMUM n=25. ← note that maximum statement required since program will not know the value of n except at run time.

READ n.

$A_i = i$ FROM $i=0$ TO n. READ X. $P = \sum_{i=0}^{n} A_i X^i$.

PRINT X,P. FINISH.

```
S0010  MAXIMUM N=25

S0020 . READ N

S0030 A SUB (I)=I FROM I=0 TO N

S0040  READ X

S0050 P=SUM WITHIN (N,I=0) OF (A SUB (I)*X RAISED TO (I))

S0060  PRINT X,P
 S0070 FINISH
```

```
         DIMENSION X21(0026)
         X14=3.14159265
         X15=2.7182818
 97777   FORMAT (E14.8)
         READ 1,97777,X72
         .57=0.
         21=(Q=1.)/ABSF(Q)
         GOTO 90001
 90002   X57=X57+1.
 90001   IF((X72-X57)*Q1)90003,90004,90004
90004   X21(I1=X57+1.)=X57
         GOTO 90002
 90003   READ 1,97777,X67
         X47= SUM(X57=0., SUMF(X57,X72),W=X21(I1=X57+1.)*X67*(X57))
        P1=X67
         P2=X47
         WRITE 2,97777,P1,P2
         END
```

Note that there is an input buffer which stores values for n and X

n

```
INPUT 12 12
  .12000000+02  .11583561+15
```

x p

FROM y=1 TO 6 COMPUTE z= $\int_0^y$ x dx AND PRINT FORMAT 1, y,z .

(outside

FORMAT 1 THE INTEGRAL FROM 0 TO x IS xxx.xxx APPROXIMATELY . FINISH.

```
S0010  FROM Y=1 TO 6 COMPUTE Z=INTEGRAL WITHIN (Y,X=0) OF (X) AND!
 PRINT FORMAT 1,Y,Z

S0020  FORMAT 1  THE INTEGRAL FROM 0 TO X IS XXX.XXX  APPROXIMATFLY !
S0030 FINISH
```

Note: in typing integrals, the integrand should be outside the $\int$ but the upper + lower limits within the symbol are

```
        X14=3.14159265
        X15=2.7182818
97777   FORMAT (E14.8)
        X101=1.
        Q1=(Q=1.)/ABSF(Q)
        GOTO 90001
90002   X101=X101+1.
90001   IF((6.-X101)+Q1)90003,90004,90004
90004   X102=XINT(X100=0.,XINT1(X100,X101),W=X100)
        P1=X101
        P2=X102
        WRITE 2,60001,P1,P2
        GOTO 90002
90003    CONTINUE
60001   FORMAT (0024H THE INTEGRAL FROM 0 TO ,I1,0004H IS ,F7.3,0017H 4
        APPROXIMATELY  )
        END
```

```
 THE INTEGRAL FROM 0 TO 1 IS    .500  APPROXIMATELY
 THE INTEGRAL FROM 0 TO 2 IS   2.000  APPROXIMATELY
 THE INTEGRAL FROM 0 TO 3 IS   4.500  APPROXIMATELY!
 THE INTEGRAL FROM 0 TO 4 IS   8.000  APPROXIMATELY
 THE INTEGRAL FROM 0 TO 5 IS  12.500  APPROXIMATELY
 THE INTEGRAL FROM 0 TO 6 IS  18.000  APPROXIMATELY
```

```
ATOM=5. PRINT ATOM. FINISH.
```

ERROR; SHOULD HAVE Declared. SPECIAL VARIABLES ATOM, or DIMENSION ATOM=1

```
S0010 A*T*O*M=5

S0020  PRINT A*T*O*M
S0030 FINISH


        X14=3.14159265
        X15=2.7182818
97777   FORMAT (F14.8)
        X21*X63*X46*X44=5.
        P1=X21*X63*X46*X44
        WRITE 2,97777,P1
        END

DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

[illegible]

[illegible]

FROM X= -5 BY .1 TO 3 COMPUTE $Q=\sum_{I=1}^{10} C_I X^I$ AND IF $|Q| \leq .5$ THEN PRINT X,Q.

[illegible]

```
S0010  REAL C SUB (I) FROM I=1 TO 10   EXECUTION 1 OF 2

S0020  FROM X=-5 BY .1 TO 3 COMPUTE Q=SUM:WITHIN (10,I=1) OF:(C:SUP (
I)*X RAISED TO (I)) AND  IF ABS(Q) LESS THAN OR EQUAL TO .5 THEN
 PRINT X,Q
S0030 FINISH


        DIMENSION X23(0011)
        X14=3.14159265
        X15=2.7182818
97777   FORMAT (E14.8)
        X57=1.
        Q1=(Q=1.)/ABSF(Q)
        GOTO 90001
90002   X57=X57+1.
90001   IF((10.-X57)*Q1)90003,90004,90004
90004   READ 1,97777,X23(I1=X57+1.)
        GOTO 90002
90003   X67=-5.
        Q2=(Q=.1)/ABSF(Q)
        GOTO 90005
90006   X67=X67+.1
90005   IF((3.-X67)*Q2)90007,90010,90010
90010   X50= SUM(X57=1., SUM1(X57,10.),W=X23(I1=X57+1.)*X67:(X57))
        IF(ABSF(X50) -(R1=(.5)))90011,90011,90012
90011   P1=X67
        P2=X50
        WRITE 2,97777,P1,P2
90012   GOTO 90006
90007   CONTINUE
        END
```

C_1 C_2 C_3 C_9 C_{10}

```
INPUT 2 7 3 9 1 6 7 5 55 51
 -.40000000-00  .35547382-00
 -.30000000-00  .21859741-01
 -.20000000-00 -.12963620-00
 -.10000000-00 -.13210451-00
 -.23719621-08 -.47439244-08
  .99999997-01  .27391680-00
```

← input data typed in at program request

X   Q

```
S0010  READ C SUB (I) FROM I=1 TO 10
```

EXECUTION 2 OF 2

```
S0020  FROM X=-5 BY .1 TO 3 COMPUTF:Q=SUM WITHIN (10,I=1) OF (C SUF:(-
I)*X RAISEE TO (I)) AND  IF ABS(Q) LESS THAN OR FQUAL TO .5 THEN
 PRINT X,Q
S0030 FINISH


        DIMENSION X23(0011)
        X14=3.14159265
        X15=2.7182818
97777   FORMAT (E14.8)
        X57=1.
        Q1=(Q=1.)/ABSF(Q)
        GOTO 90001
90002   X57=X57+1.
90001   IF((10.-X57)*Q1)90003,90004,90004
90004   READ 1,97777,X23(I1=X57+1.)
        GOTO 90002
90003   X67=-5.
        Q2=(Q=.1)/ABSF(Q)
        GOTO 90005
90006   X67=X67+.1
90005   IF((3.-X67)*Q2)90007,90010,90010
90010   X50= SUM(X57=1., SUM1(X57,10.),W=X23(I1=X57+1.)*X67↑(X57))
        IF(ABSF(X50) -(R1=(.5)))90011,90011,90012
90011   P1=X67
        P2=X50
        WRITE 2,97777,P1,P2
90012   GOTO 90006
90007   CONTINUE
        END
```

program requests input data.

C1 C2 C9 C10

```
INPUT 1 2 3 4 5 6 7 8 9 10
```

x Q

```
 -.60000000+00  .38971699-00
 -.50000000+00  .28125000-00
 -.40000000-00  .19623936-00
 -.30000000-00  .12249988-00
 -.20000000-00  .61111211-01
 -.10000000-00  .17355371-01
 -.23719621-05  .11252409-16
  .99999997-01  .83456788-01
  .19999999-00  .11249945-00
  .29999999-00  .31221596-00
```

← Note.

FROM X=3 BY 0.5 TO 13 PRINT $Q=3X^2+7X^3-19$. FINISH.

```
S0010  FROM X=3 BY 0.5 TO 13 PRINT Q=3*X RAISED TO (2)+7*X
 RAISED TO (3)-19
S0020 FINISH
```

```
        X14=3.14159265
        X15=2.7182818
97777   FORMAT (F14.8)
        Xe7=3.
        Q1=(Q=0.5)/ABSF(Q)
        GOTO 90001
90002   X67=X67+0.5
90001   IF((13.-X67)*Q1)90003,90004,90004
90004   P1=X50=3.*X67↑(2.)+7.*X67↑(3.)-19.
        WRITE 2,97777,P1
        GOTO 90002
90003   CONTINUE
        END
```

```
.19699999+03
.31787499+03
.47699999+03
.67962499+03
.93099999+03
.12363749+04
.16009999+04
.20301249+04
.25289[illegible]4
.31028749+04
.37569999+04
.44966249+04
.53269999+04
.62533749+04
.72809999+04
.84151249+04
.96609999+04
.11023874+05
.12508999+05
.14121624+05
.15866999+05
```

Output

MAXIMUM n=30.

READ n.

A_1=1 FROM 1=0 TO n. READ X.

$$P(n) = \sum_{1=0}^{n} A_1 x^1 .$$

PRINT P, n. PRINT FORMAT 1, n,X,P.

FORMAT 1 THE POLYNOMIAL OF DEGREE x , ARGUMENT xx.xx , = XXX.XXX .

FROM 1=0 TO n PRINT 1 (2) , A_1 (2) .

FINISH.

```
S ØØ1Ø  MAXIMUM N=3Ø

S ØØ2Ø  FEAL N

S ØØ3Ø A SUE (I)=I FFOM I=Ø TO N

SØØ4Ø  FEAL X

S ØØ5Ø P=SUM WITHIN (N,I=Ø) OF (A SUE (I)*X FAISFL:TO:(I))

SØØ6Ø  PFINT P,N

S ØØ7Ø  PFINT FOFMAT 1,N,X,F

SØØ8Ø  FOFMAT 1 THE POLYNOMIAL OF LFGFFF:X , AFGUMFNT XX.XX ,:=:XXX.X-
XX

S ØØ9Ø  FFOM I=Ø TO N PFINT I(2),A SUF (I)(2)
SØ1ØØ FINISH
```

```
          DIMENSION X21(0031)
         X14=3.14159265
         X15=2.7182818
 97777   FORMAT (E14.8)
         READ 1,97777,X72
         X57=0.
          Q1=(Q=1.)/ABSF(Q)
         GOTO 90001
 9 0002   X57=X57+1.
 9 0001   IF((X72-X57)*Q1)90003,90004,90004
90004   X21(I1=X57+1.)=X57
         GOTO 90002
 9 0003   READ 1,97777,X67
         X47= SUM(X57=0., SUM1(X57,X72),W=X21(I)=X57+1.)*X67↑(X57))
        P1=X47
        P2=X72
        WRITE 2,97777,P1,P2
         P1=X72
          P2=X67
          P3=X47
          WRITE 2,60001,P1,P2,P3
 6 0001   FORMAT (0025HTHE POLYNOMIAL OF DEGREE ,I1,0012H , ARGUMENT ,F5.
        2,0005H , = ,F7.3,0002H   )
         X57=0.
          Q2=(Q=1.)/ABSF(Q)
         GOTO 90005
 9 0006   X57=X57+1.
 9 0005   IF((X72-X57)*Q2)90007,90010,90010
90010   P1=X57
          P2=X21(I1=X57+1.)
 90011   FORMAT (I8,6X,I8,6X)
         WRITE 2,90011,P1,P2
         GOTO 90006
 9 0007   CONTINUE
        END
```

INPUT 5 5

```
  .18554999+05  .50000000+01
THE POLYNOMIAL OF DEGREE 5 , ARGUMENT  5.00, = 1.185+05
      0              0
       1              1
       2              2
       3              3
       4              4
       5              5
```

```
MAXIMUM n=20.


PRINT $X_i$=1 FROM i=1 TO 10.  {LENGTH OF X IS KNOWN}
READ n.  FROM i=1 TO n PRINT $Y_i$=1.  {THE LENGTH OF Y IS FIXED BY n}

PRINT Z = $j^2$ FROM j=1 UNTIL Z ≥ 94.  { STOP  WHEN Z ≥ 94 }

PRINT n.
FINISH.
```

```
S0010  MAXIMUM N=20

S0020  PRINT X SUB (I)=I FROM I=1 TO 10

S0030

 READ N

S0040  FROM I=1 TO N PRINT Y SUB (I)=1

S0050

 PRINT Z=J RAISED TO (2) FROM J=1 UNTIL Z GREATER THAN OR EQUAL TO 94

S0060

 PRINT N
 S0070 FINISH
```

Execution on next page

```
        DIMENSION X67(0011),X70(0021)
       X14=3.14159265
        X15=2.7182818
 97777  FORMAT (E14.8)
        X57=1.
        Q1=(Q=1.)/ABSF(Q)
        GOTO 90001
 90002  X57=X57+1.
 90001  IF((10.-X57)*Q1)90003,90004,90004
90004  P1=X67(I1=X57+1.)=X57
        WRITE 2,97777,P1
        GOTO 90002
 90003  READ 1,97777,X72
        X57=1.
        Q2=(Q=1.)/ABSF(Q)
        GOTO 90005
 90006  X57=X57+1.
 90005  IF((X72-X57)*Q2)90007,90010,90010
90010  P1=X70(I1=X57+1.)=X57
       WRITE 2,97777,P1
        GOTO 90006
 90007  X60=1.
        Q3=(Q=1.)/ABSF(Q)
        GOTO 90011
 90012  X60=X60+1.
 90011  IF((X71-(94.)))90014,90013,90013
90014  P1=X71=X60↑(2.)
        WRITE 2,97777,P1
        GOTO 90012
 90013  P1=X72
        WRITE 2,97777,P1
        END
```

```
.10000000+01
.20000000+01
.30000000+01
.40000000+01
.50000000+01
.60000000+01
.70000000+01
.80000000+01
.90000000+01
.10000000+02INPUT 15
.10000000+01
.20000000+01
.30000000+01
.40000000+01
.50000000+01
.60000000+01
.70000000+01
.80000000+01
.90000000+01
.10000000+02
.11000000+02
.12000000+02
.13000000+02
.14000000+02
.15000000+02
```

x_i

n

y_i

```
.10000000+01
.39999999+01
.89999999+01
.15999999+02
.24999999+02
.35999999+02
.48999999+02
.63999999+02
.80999999+02
.99999999+02
.15000000+02
```

Z

TYPING ERROR CORRECTED WITH OVERTYPE →

```
FOR 1=1,2,...,10  PRINT 1 (2).
FOR J=5(10)55 PRINT J (2).
PRINT LABEL  ALPHA,BETA,GAMMA,ZETA.
FINISH.
```

```
S0010  FOR I=1,2,...,10 PRINT I(2)

S0020  FOR J=5(10)55 PRINT J(2)

S0030  PRINT  LABEL ALPHA,BETA,GAMMA,ZETA
S0040 FINISH
```

```
        X14=3.14159265
        X15=2.7182818
97777   FORMAT (E14.8)
        X57=1.
        Q1=(Q=2.-(1.))/ABSF(Q)
        GOTO 90001
90002   X57=X57+2.-(1.)
90001   IF((10.-X57)*Q1)90003,90004,90004
90004   P1=X57
90005   FORMAT (I8,6X)
        WRITE 2,90005,P1
        GOTO 90002
90003   X60=5.
        Q2=(Q=10.)/ABSF(Q)
        GOTO 90006
90007   X60=X60+10.
90006   IF((55.-X60)*Q2)90010,90011,90011
90011   P1=X60
90012   FORMAT (I8,6X)
        WRITE 2,90012,P1
        GOTO 90007
90010   CONTINUE
90013   FORMAT (4X,0005HALPHA,5X,5X,0004HBETA,5X,4X,0005HGAMMA,5X,5X,00
        04HZETA)
        WRITE 2,90013
        END
```

OUTPUT

```
     1
     2
     3
     4
     5
     6
     7
     8
     9
    10
     5
    15
    25
    35
    45
    55
  ALPHA          BETA          GAMMA          ZETA
```

DO STATEMENT 5 FROM Y=1 TO 11.

PRINT Y ↑2 . STATEMENT 5. FINISH.

```
S0010  LOOP  STATEMENT 5 FROM Y=1 TO 11
S0020  PRINT Y(2)
S0030  STATEMENT 5
S0040 FINISH


        X14=3.14159265
        X15=2.7182818
97777   FORMAT (E14.8)
        X70=1.
        Q1=(Q-1.)/ABSF(Q)
        GOTO 90001
90002   X70=X70+1.
90001   IF((11.-X70)*Q1)90003,90004,90004
90004   P1=X70
90005   FORMAT (I8,6X)
        WRITE 2,90005,P1
        GOTO 90002
90003   CONTINUE
70005   CONTINUE
        END
```

```
  1
  2
  3
  4
  5
  6
  7
  8
  9
 10
 11
```

PRINT Z= $\frac{\text{SIN } \theta}{\text{COS } \theta} \sqrt{\frac{1}{(\text{COS } \theta)^2}}$

FROM θ=.1π BY .05 TO .45π .

FINISH.

```
S0010  PRINT Z=((SIN(THETA))/(COS(THETA)))*SQRT(((1)/((COS(THETA))
 RAISED TO (2))))

 FROM THETA=.1*PI BY .05 TO .45*PI
S0020 FINISH



        X14=3.14159265
        X15=2.7182818
97777   FORMAT (E14.8)
        X33=.1*X14
        Q1=(Q=.05)/ABSF(Q)
        GOTO 90001
90002   X33=X33+.05
90001   IF((.45*X14-X33)*Q1)90003,90004,90004
90004   P1=X71=((SINF(X33))/(COSF(X33)))*SQRTF(((1.)/((COSF(X33))↑(2.))
        ))
        WRITE 2,97777,P1
        GOTO 90002
90003   CONTINUE
        END
```

```
.34164297-00
.40790803-00
.48018216-00
.55987554+00
.64870550+00
.74879297+00
.86279701+00
.99410211+00
.11470632+01
.13274866+01
.15430055+01
.18041134+01
.21254097+01
.25277292+01
.30416686+01
.37135437+01
.46164769+01
.58710427+01
.76879986+01
.10463164+02
.14993454+02
.23250644+02
```

OUTPUT

R=15-LN(e^{15})+1 AND D=9-LOG(10^{9})+3.
PRINT R,D. FINISH.

NOTE FACT THAT
COMPUTER INTERPRETED
9-LOG(10^{9})+3
CORRECTLY!

```
S0010 R=15-LN (E RAISED TO (15))+1 AND D=9-LOG(10 RAISED TO (9))+3

S0020  PRINT R,D
S0030 FINISH


        X14=3.14159265
        X15=2.7182818
97777   FORMAT (E14.8)
        X51=15.-LOGF(X15↑(15.))+1.
        X24=9.-CLOGF(10.↑(9.))+3.
        P1=X51
        P2=X24
        WRITE 2,97777,P1,P2
        END


   .10000001+01  .29999999+01
```

```
P_1 = .99 FROM 1=1 TO 100.
{P_1 IS THE RELIABILITY INDEX  FOR COMPONENT 1}

Q=   $\prod_{1=1}^{100} P_1$.   {PRODUCT  FUNCTION}   PRINT Q.

R=100Q.
{R=THE TOTAL DEVICE RELIABILITY FOR 100 COMPONENTS}
PRINT FORMAT 1, R.
FORMAT  1 THE DEVICE  IS xx.xxxx PER CENT RELIABLE.
FINISH.
```

```
50010 P SUP (I)=.99 FROM I=1 TO 100

50020

Q=PRODUCT WITHIN (100,I=1) OF (P SUP (I))

50030  PRINT Q        NOTE EXPLICIT MULTIPLICATION

50040 R=100*Q

50050

 PRINT FORMAT 1,R

50060  FORMAT 1 THE DEVICE  IS XX.XXXX PER CENT RELIABLE
50070 FINISH
        DIMENSION X47(0101)
        X14=3.14159265
        X15=2.7182818
97777   FORMAT (E14.8)
        X57=1.
        Q1=(Q=1.)/ABSF(Q)
        GOTO 90001
90002   X57=X57+1.
90001   IF((100.-X57)*Q1)90003,90004,90004
90004   X47(I1=X57+1.)=.99
        GOTO 90002
90003   X50= PROD(X57=1., PROD1(X57,100.),W=X47(I1=X57+1.))
        P1=X50
        WRITE 2,97777,P1
        X51=100.*X50
        P1=X51
        WRITE 2,60001,P1
60001   FORMAT (0015HTHE DEVICE  IS ,F7.4,0018H PER CENT!RELIABLE)
        END
```

```
  .36603233-00
THE DEVICE  IS  .3660+02 PER CENT RELIABLE
```

```
FROM i=1 TO 11 AND k=99 TO 102 PRINT i {2} ,k {3} .
{NOTE THAT OUTER LOOP IS EXERCISED FIRST}

FINISH.
```

```
S0010  FROM I=1 TO 11 AND K=99 TO 102 PRINT I(2),K(3)

S0020
 FINISH
```

```
        X14=3.14159265
        X15=2.7182818
97777   FORMAT (E14.8)
        X61=99.
        Q1=(Q=1.)/ABSF(Q)
        GOTO 90001
90002   X61=X61+1.
90001   IF((102.-X61)*Q1)90003,90004,90004
90004   X57=1.
         Q2=(Q=1.)/ABSF(Q)
        GOTO 90005
90006   X57=X57+1.
90005   IF((11.-X57)*Q2)90007,90010,90010
90010   P1=X57
        P2=X61
90011   FORMAT (I8,6X,I8,6X)
        WRITE 8,90011,P1,P2
        GOTO 90006
90007   GOTO 90002
90003   CONTINUE
        END
```

THEN THIS

```
     i            k                          i            k
     1           99                          1          101
     2           99                          2          101
     3           99                          3          101
     4           99                          4          101
     5           99                          5          101
     6           99                          6          101
     7           99                          7          101
     8           99                          8          101
     9           99                          9          101
    10           99                         10          101
    11           99                         11          101
     1          100                          1          102
     2          100                          2          102
     3          100                          3          102
     4          100                          4          102
     5          100                          5          102
     6          100                          6          102
     7          100                          7          102
     8          100                          8          102
     9          100                          9          102
    10          100                         10          102
    11          100                         11          102
```

THIS WAS PRINTED OUT FIRST

```
FROM N=1 BY .66 TO 20
PRINT  FORMAT  1 , N, TRUNCATE (N).

FORMAT  1 FOR N=xx.xxxx   THE TRUNCATE IS xx.

FINISH.
```

```
S0010  FROM N=1 BY .66 TO 20 PRINT FORMAT 1,N,TRUNCATE (N)

S0020  FORMAT 1 FOR N=XX.XXXX   THE TRUNCATF!IS XX
S0030 FINISH
```

```
          X14=3.14159265
          X15=2.7182818
 97777    FORMAT (E14.8)
          X45=1.
          Q1=(Q=.66)/ABSF(Q)
          GOTO 90001
 90002    X45=X45+.66
 90001    IF((20.-X45)*Q1)90003,90004,90004
90004    P1=X45
           P2=XINTG(X45)
          WRITE 2,60001,P1,P2
          GOTO 90002
 90003    CONTINUE
 6 0001    FORMAT (0006HFOR N=,F7.4,0019H   THE TRUNCATE!IS!,I2)
         END
```

```
FOR N= 1.0000   THE TRUNCATE IS  1
FOR N= 1.6600   THE TRUNCATE IS  1
FOR N= 2.3200   THE TRUNCATE IS  2
FOR N= 2.9800   THE TRUNCATE IS  2
FOR N= 3.6400   THE TRUNCATE IS  3
FOR N= 4.3000   THE TRUNCATE IS  4
FOR N= 4.9600   THE TRUNCATE IS  4
FOR N= 5.6200   THE TRUNCATE IS  5
FOR N= 6.2800   THE TRUNCATE IS  6
FOR N= 6.9400   THE TRUNCATE IS  6
FOR N= 7.6000   THE TRUNCATE IS  7
FOR N= 8.2600   THE TRUNCATE IS  8
FOR N= 8.9200   THE TRUNCATE IS  8
FOR N= 9.5800   THE TRUNCATE IS  9
FOR N= .1024+02    THE TRUNCATE IS 10
FOR N= .1089+02    THE TRUNCATE IS 10
FOR N= .1155+02    THE TRUNCATE IS 11
FOR N= .1221+02    THE TRUNCATE IS 12
FOR N= .1287+02    THE TRUNCATE IS 12
FOR N= .1353+02    THE TRUNCATE IS 13
FOR N= .1419+02    THE TRUNCATE IS 14
FOR N= .1485+02    THE TRUNCATE IS 14
FOR N= .1551+02    THE TRUNCATE IS 15
FOR N= .1617+02    THE TRUNCATE IS 16
FOR N= .1683+02    THE TRUNCATE IS 16
FOR N= .1749+02    THE TRUNCATE IS 17
FOR N= .1815+02    THE TRUNCATE IS 18
FOR N= .1881+02    THE TRUNCATE IS 18
FOR N= .1947+02    THE TRUNCATE IS 19
```

FROM θ=.1 BY .2 TO 3 COMPUTE α=COS (θ) AND γ=COS^{-1} (α)

AND PRINT $\theta,\gamma,\theta-\gamma$.

FINISH.

```
S0010  FROM THETA=.1 BY .2 TO 3 COMPUTE ALPHA=COS(THETA) AND GAMMA=
ARCCOS(ALPHA) AND  PRINT THETA,GAMMA,THETA-GAMMA
S0020 FINISH


         X14=3.14159265
         X15=2.7182818
 97777   FORMAT (E14.8)
         X33=.1
         Q1=(Q=.2)/ABSF(Q)
         GOTO 98001
 98002   X33=X33+.2
 98001   IF((3.-X33)*Q1)98003,98004,98004
 98004   X55=COSF(X33)
         X103=ARCOSF(X55)
         P1=X33
         P2=X103
         P3=X33-X103
         WRITE 2,97777,P1,P2,P3
         GOTO 98002
 98003    CONTINUE
         END
```

```
.10000000-00  .10000000-00 -.12587406-08
.30000000-00  .30000000-00 -.20954757-08
.50000000-00  .50000000+00 -.11932570-08
.70000000+00  .70000000+00 -.23574182-08
.89999999+00  .90000000+00 -.22700957-08
.11000000+01  .11000000+01 -.34342519-08
.13000000+01  .13000000+01 -.29183838-08
.14999999+01  .15000000+01 -.36088749-08
.16999999+01  .17000000+01 -.27357600-08
.19000000+01  .19000000+01 -.38267983-08
.20999999+01  .21000000+01 -.27939677-08
.22999999+01  .23000000+01 -.19790684-08
.24999999+01  .24999999+01  .14901161-07
.26999999+01  .26999997+01  .28570587-06
.28999999+01  .28999977+01  .22012973-05
```

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